SUBCOURSE EDITION

SS0330 9

INTRODUCTION TO TELEPHONE AND TELEGRAPH TRANSMISSION

AIPD

READINESS/ PROFESSIONALISM THRU GROWTH

THE ARMY INSTITUTE FOR PROFESSIONAL DEVELOPMENT

ARMY CORRESPONDENCE COURSE PROGRAM

SIGNAL SUBCOURSE 330

INTRODUCTION TO TELEPHONE AND TELEGRAPH TRANSMISSION

INTRODUCTION

On May 24, 1844, Samuel Morse sent his first message from Washington, D.C. to Baltimore, Md. He used a series of electrical pulses over a wire line to operate a magnet. The magnet produced clicks and recorded a code of dots and dashes on a moving paper tape. This code represented letters of the alphabet and was translated into words.

In 1876 Alexander Graham Bell devised and patented the first capable telephone system. Until the invention of the telephone, the distance over which the human voice could be used for communication was limited by the lung power of the speaker and by the ear sensitivity of the listener.

The use of the telephone and the teletypewriter in military communications systems has provided one of the most reliable means of sending messages quickly and accurately. The communications specialist must therefore have a working itinerary with each of the various types of equipment.

In this subcourse you will learn the principles of sound as well as the theory operation of telephone and teletypewriter systems.

STUDENT ACTIONS

Specific performances and lesson objectives are listed at the beginning of each lesson. Here is a brief summary of these objectives.

1. To enable you to understand what sound waves are, what makes up a telephone and what is represented by electronic symbols on schematics and other diagrams. You will also learn how a telephone is constructed and what makes it operate.

2. To teach you the operational characteristics of a local-battery telephone system and a common battery telephone system.

3. To enable you to understand the construction principles and types of circuits used with various transmission lines. To teach you the types of telephone operation, power gain and/or loss, simplex and phantom circuits, thus providing you a better understanding of the world of telephone communications.

4. To enable you to understand operation of teletype circuits, teletype operation, the Baudot code and identify terms and symbols peculiar to teletype operations.

*** * * IMPORTANT NOTICE * * ***

THE PASSING SCORE FOR ALL ACCP MATERIAL IS NOW 70%.

PLEASE DISREGARD ALL REFERENCES TO THE 75% REQUIREMENT.

SUBCOURSE SS0330 .... Introduction to Telephone and Telegraph Transmission

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LESSON 1

SOUND AND TELEPHONY

OBJECTIVE:

Action:	You will describe the characteristic of sound waves, identify electronic symbols on a telephone system schematic diagram, analyze the construction of a telephone transmitter and receiver.
Conditions:	You will be provided the lesson material and a lesson exercise sheet.
Standard:	You must respond correctly to at least 17 of the 20 questions in the lesson exercise.

CREDIT HOURS: 2

TEXT ASSIGNMENT: Read inclosed text

MATERIALS REQUIRED: Pencil or pen

SUGGESTIONS: None

CHAPTER 1

SOUND

1. Sound and Telephony.

Until the invention of the telephone, the distance over which the human voice could be used for communication was limited by the lung power of the speaker and the ear sensitivity of the hearer. This limited distance could be extended by a device which concentrates voice power in a given direction. The device is called a megaphone. Notice that the word "mega-phone" and "tele-phone" are made up in part from the Greek word "phone," which means sound. The word "megaphone"--simply means a "big sound" while the word "telephone" means sound at a distance or far sound.

a. The telephone solves the problem of distance limitation of point to point sound transfer. Many stages of development were necessary to bring the telephone to its present efficiency and flexibility. Development was rapid and today the service provided by the telephone reaches almost everywhere. A business executive or a commanding general, by picking up a telephone, can communicate with an associate in the next room, in his immediate area, or on the other side of the world.

b. The sound of a speaker's voice is not actually transmitted over long distances. But the small voice power of the speaker is converted into electrical energy, transmitted over wires to a distant point and reconverted back to a sound like that generated by speaker. While in the form of electrical energy this sound may be amplified at will and transmitted over wires to any given point.

Radio communication, developed later as a better solution to the same problem, transmits electrical energy without wires and therefore in its early stages of development was called the wireless to distinguish it from the telephone and telegraph. The radio telephone, a more recent development, uses both wire and wireless forms of transmission.

c. Any telephone system begins and ends with sound; therefore, this chapter will concern itself with the origin and characteristics of sound waves and will also serve as an introduction to the elements and operational techniques of the basic telephone system. A major portion of this manual is devoted to an analysis of local-battery and common battery circuits. Both are used in Army communications systems.

2. Nature of Sound.

Sound is a sensation in the nervous system resulting from vibrations of the delicate membranes in the ear (ear drum). An analysis of sound as a sensation is beyond the scope of this text, but the cause of sound by physical vibrations can be analyzed and measured with accuracy.

Figure 1 shows how sound results from the rapid vibration of a rigid or semirigid body. If a pencil is held lightly against one of those vibrating bodies the physical motion can be felt by the hand. These same vibrations are recognized by the ear as sound. The physical medium between the source of vibrations and the ear is the air which is sufficiently dense, at atmospheric pressure, to be set in motion by the vibrating body and deliver the vibration to the sensitive membranes of the ear.

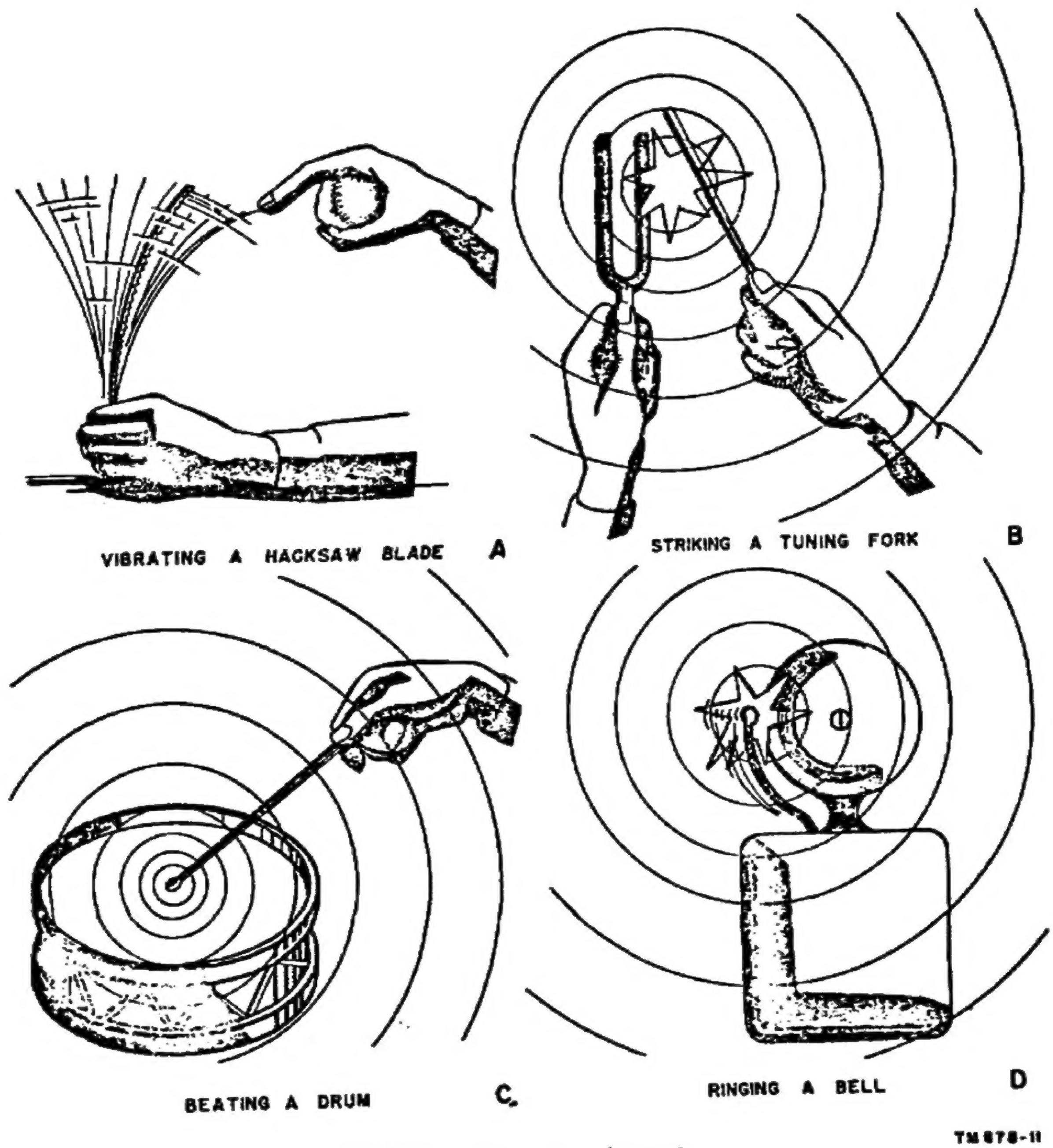

FIGURE 1. Generation of Sounds

3. <u>Transmission of Sound</u>.

a. An important fact to remember is that sound, unlike light and electromagnetic (radio) energy, must have a medium within which to travel. Although electricity and light can be transmitted within a vacuum, sound cannot. When sound is transmitted the medium between the source and the listener is usually air, but other mediums such as liquids or solids may be used. The American Indian used to press his ear to the ground to detect far away footsteps. Little boys playing around railroad tracks used to put their ears to the track to detect the sound of oncoming trains long before the train could be heard or seen. In both cases, the denser medium carried sound farther than it traveled in air. This principle is also used in the underwater detection of ships. Sensitive listening devices attached to the hull of the ship pick up the sound of propeller vibrations carried by the sea from other ships in the area.

4. <u>Sound Waves</u>.

The motion of air molecules set up by a body vibrating in the air travel outward in all directions from the vibrating source. The manner in which the molecules travel are called <u>waves</u>, sound waves to be more precise. This can be better understood by considering a vibrating strip of metal such as the hacksaw blade in figure 2.

a. A hacksaw blade is fastened to a table as shown in figure 2A, and caused to vibrate rapidly back and forth. As it makes its initial trip to the right, two events of opposite nature occur as shown in figure 2B. In the first event the blade increases the pressure existing in the group of air molecules on its right causing a bunching up (condensation) of the particles on that side. In the second, the blade decreases the pressure existing in the group of particles on the left causing a dispersion (rarefaction) of the molecules on that side. Remember condensation and rarefaction occur at the same time by a single motion of the blade.

b. The blade moves back to its vertical resting position as in 2C, but motion has been given to the molecules (particles) on each side and their succeeding behavior is effected. The bunched up group on the right moves outward and away from the blade pushing against the layer of particles still farther to the right.

Great numbers of minute collisions occur and gradually but very rapidly the striking particles give up to their neighbors their own motion and bunched up arrangements. This progress outward continues, the wave of sound energy moving outward and the individual air particles that transmitted the motion remaining behind.

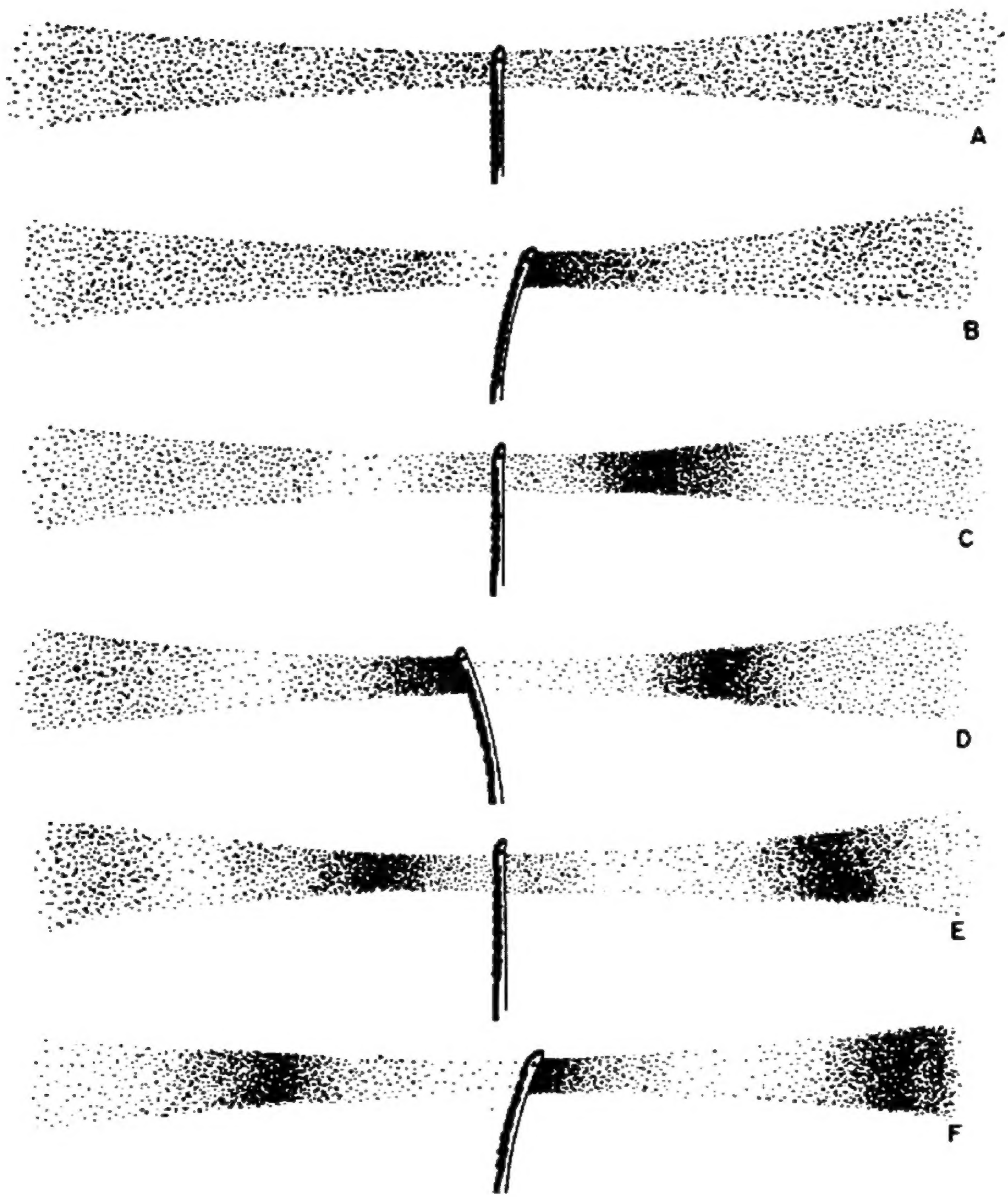

FIGURE 2.   Sound Wave Produced by
Vibrating Blade.

c. As the blade returns toward the vertical position, the condensed air modules travel outward (away from the blade) and an increasing gap occurs between the blade and the area of condensation, as shown in figure 2C. This gap moves from rarefaction to equilibrium rather rapidly because air molecules rush in to fill the area. By the time the blade returns to the vertical position, the area immediately to both the right and left of the blade has returned to its original density.

d. At this point the blade has a lot of velocity, and continues to the left as in figure 2D. It now has caused a condensation on the left side and a rarefaction on its right. The initial condensation on the right, meanwhile, has moved still farther from the blade and the initial rarefaction still farther to the left.

e. Now, you can see that at each advance of the blade on either side a crest of condensation is sent outward and at each retreat of the blade a trough of rarefaction is set up. The energy, crest to crest, was provided by a transfer of the energy of motion of the blade. This energy, as it continues its outward travel is now called a sound wave! Keep in mind that the particles which transmit the energy do not go along with it; each collides with its outside neighbor, passing its energy to the neighbor and returns close to its original position. In figure 2E the blade is back to the vertical position and normal pressure is restored. By this time, both condensations and rarefactions have moved farther out from the source and are followed by a new wave as shown in figure 2F. This process and train of waves continue to be sent out as long as the vibration continues.

5. Representation of Sound Waves.

a. Sound waves may be represented as a graph by laying out successive groups of relatively compressed air particles along a path of motion for a certain distance or certain amount of time.

(1) In figure 3 you can see a portion of figure 2E redrawn, showing the particles making up several sound waves. The alternate regions of condensation and rarefaction are moving to the right (towards the ear) as described in paragraph 4. Below this representation is a graph. On this graph the high parts and the low parts corresponding to the relative compression of air particles

along the path of the wave. Note that the highest points of the curve lie beneath the places of maximum condensation and the lowest points of the curve are beneath places of maximum rarefaction, while points of medium density are located in between the two extremes.

(2) Since the wave is moving to the right, the ear of the listener experiences variations of pressure identical to those existing along the wave illustrated in figure 3. First, the rarefaction farthest to the right and then the neighboring condensation to the left and so on. This is taking place because the entire train of waves is moving toward the ear from the left. The graph of pressure against distance at any instant and the horizontal distance may represent intervals of time.

(3) The curve of the graph represents sound waves set up by an object vibrating 400 times each second. The time required for each complete vibration as shown in the graph is 1/400th of a second, or 2.5 milliseconds.

b. The number of complete vibrations of the object that occur in one second is the same as the number of cycles of the wave in the graph that occur in 1 second. This number is called the frequency of the wave. A cycle is a complete set of

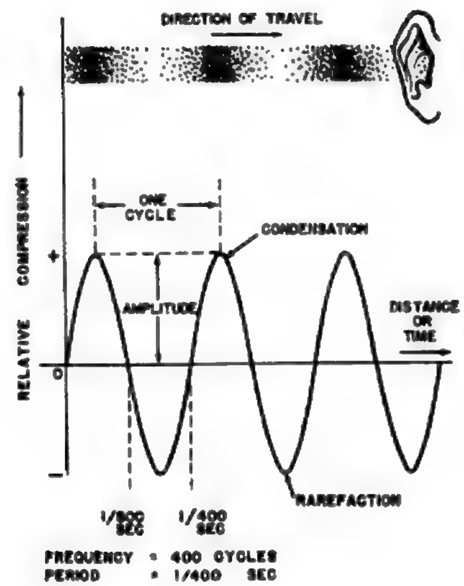

FIGURE 3. Waveform of Simple Sound

pressure values, one position peak to the next (condensation to condensation) anywhere along the path of the wave. The words per second are omitted but understood in referring to frequency so that the frequency is expressed only in cycles. Sometimes cps (cycles per second) is used. The time required for one cycle to occur is called the period of the wave. Cycles per second is the American unit of measurement for frequency while Hertz (Hz) is the international unit of measurement. (1 Hz = 1 cps). Initially, cycles or cps will be used in this text; however, later the term Hertz will be used. On the left hand side of the graft you can recognize the zero axis--the value of the wave measured from the zero axis to the maximum value of the wave is called the "amplitude." The expressed value of the amplitude of the wave depends upon the units used to measure the relative compression of the particles or their effect.

6. Velocity and Wavelength.

a. Velocity. The length of time required for sound to travel from one point to another is called speed or velocity. In air at 0° C (32° F) the velocity of sound waves is about 1,090 feet per second. As the temperature rises so does the speed of sound. At 20° C (69° F) the velocity of sound is about 1,130 feet per second. As the medium increases in density the velocity increases. For example, in water, sound travels at 4,700 feet per second. In solids, sound velocity is usually many times greater than in air. Light waves and electromagnetic waves travel much faster than sound, 186,000 miles per second which is about 700,000 times faster than sound. You can readily recognize this difference in velocity if you recall that you see the lightning flash before you hear the report. At ordinary speaking distances the time required for sound to travel from one person to another is too short to be of any consequence. However, it can be quite disturbing when the distance separating the speaker from the listener is relatively great, such as a large auditorium or a stadium.

b. Wavelength. A sound wave, like a light wave or electromagnetic wave, may be identified by its wavelength. The wavelength is the distance between successive condensations or successive rarefactions, along the path of the sound. In figure 3, the wavelength is the distance covered by that portion of the wave designated as one cycle. The wavelength of a soundwave can be calculated by using the formula:

$$\text{Wavelength (in feet)} = \frac{\text{Velocity of Sound}}{\text{Frequency of Sound}}$$

A sound wave with a frequency of 1,000 cycles, traveling at 1,130 feet per second would be:

$$\text{Wavelength (in feet)} = \frac{1130}{1000}, \text{ Wavelength} = 1.13 \text{ ft}$$

Another example is a 400 cycle sound at the same velocity (represented in figure 3).

$$\text{Wavelength (in feet)} = \frac{1130}{400} = 2.82 \text{ ft}$$

It can be noted here, as can be seen by the two problems discussed, as the frequency increases, the wavelength decreases and as the frequency decreases the wavelength increases, providing the medium remains the same. Audible sounds from 20 to 20,000 cps have wavelengths ranging from 55 feet to 2/3 of an inch using air as a medium. Electromagnetic waves of the same frequencies would range in length from about 9,300 miles to approximately 9.3 miles. The reason the electromagnetic wavelengths are so great is because the velocity is so great. Lightwaves have the same velocity as electromagnetic waves but the frequency is so extremely high that the resulting wavelength is less than 1/1,000,000 of an inch.

7. Complex Sounds.

a. Harmonics. Most of the sound used in telephony is not as simple as that illustrated in figure 3. The type of sound we hear or use in telephony is called complex sounds. Complex sounds consist of two or more simple sounds each having its own frequency and amplitude. Any complex sound may be separated rated into its component simple sounds and their frequencies as shown in figure 4. The lowest frequency contained in this complex sound is called the fundamental frequency sometimes referred to as simply the fundamental. All others are called harmonic frequency or overtones. Harmonic frequencies are whole-number multiples of the fundamental. For example, if the fundamental frequency of a sound is 400 cycles the fourth harmonic would be four times (4x) the fundamental or 1600 cycles, or the fifth harmonic = 5 x 400 or 2,000 cycles. With this definition then we could say the fundamental is the first harmonic of a frequency of sound.

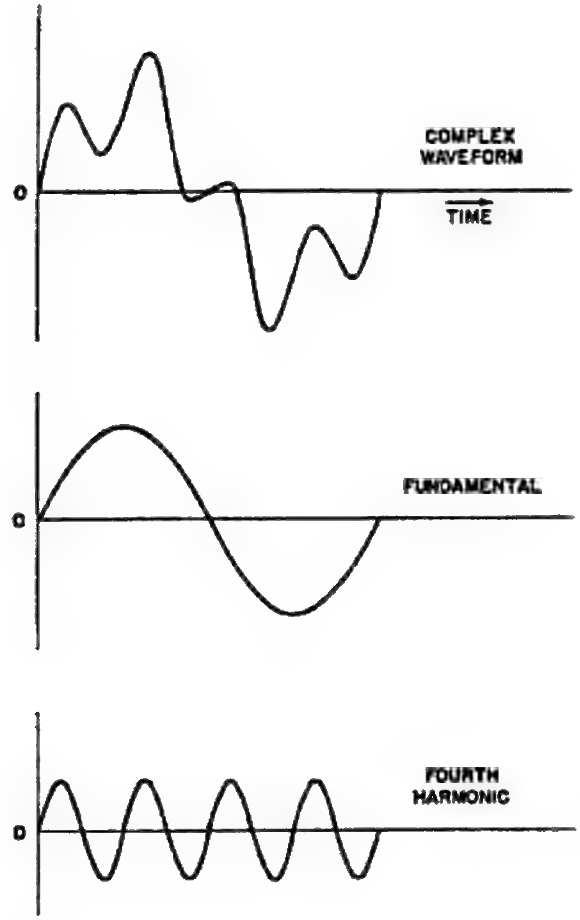

FIGURE 4. Analysis of Complex Waveform

b. Voice Sounds. Voice sounds are complex sounds and contain different sets of harmonics which helps us to recognize the voices of different people and makes the voice expressive of feelings such as gladness, sorrow and anger. Harmonics are important in telephony, because if the telephone system suppresses or distorts the voice harmonics it makes the transmitting voice less intelligible. Basic voice sounds occur in the variation of the five basic vowels (a, e, i, o, u) and the consonants. This difference in vowel sounds can be seen in a waveform. Study the waveforms in figure 5 and note the difference in them.

c. Musical Sounds. There are different harmonics contained in the sound waves produced by different musical instruments playing the same note. These enable the listener to recognize one instrument from another in the same way harmonics in voice produced sounds identify the voice. Middle C struck on a piano is distinguished easily from the same note played on a violin. A musical notes richness in harmonics makes it pleasing to the ear. Chords are pleasing because all the harmonics of the individual notes blend. The waveform of a musical note is illustrated in figure 5B.

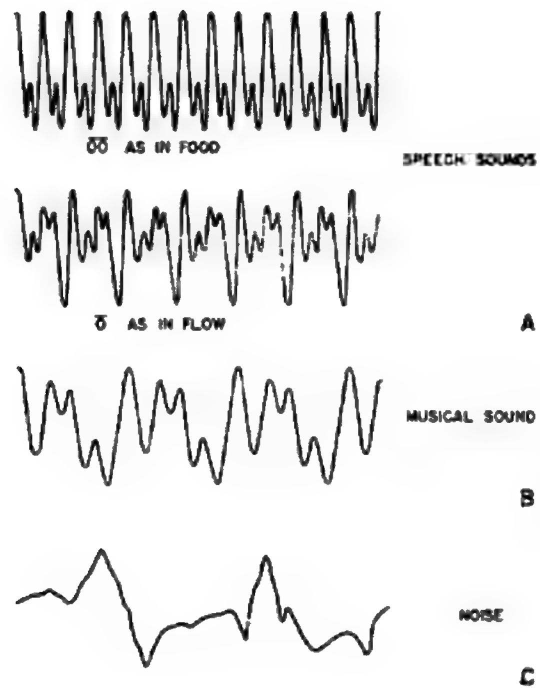

FIGURE 5. Waveform of Speech, Music, and Noise

d. Noise. Looking at waveforms one can distinguish either speech or music by the irregularity of its waveform. If you examine the waveform illustrated in figure 5 you will notice a regularity of variation in the speech and music. Portions of the wave recur at regular intervals in A and B while in the waveform representing noise (C) there is no perceptible regularity. This results in a relatively unpleasant sensation. You will find it is also difficult to determine the frequency content of noise. At times the random or background noise in a room has a disturbing effect on a listener, and may actually render a conversation unintelligible. Speech or music when it becomes distorted and unintelligible becomes mere noise.

8. Characteristics of Sound.

All sound produced by musical instruments and the human voice has three identifying characteristics: pitch, loudness, and timbre.

a. The Pitch of Sound. The pitch of a sound is determined by its frequency. The voice of a soprano is higher in pitch than the voice of a basso, the yowling of an alley cat is higher in pitch than the sound of a fog horn. In the case of a complex wave, the pitch is determined by the fundamental frequency. The higher the frequency the higher the pitch. The highest frequency the human ear can detect is about 20,000 cycles per second (cps) and the lowest is about 20 cycles (cps). There are some sounds with frequencies well above the audible range (above 20,000 cps) they are called ultrasonics. Low in the audible range is the musical standard pitch which is 256 cps. The common name for this musical standard is middle "C."

b. Loudness of Sound. The loudness, the intensity, or the strength of the sound refers to the amount or strength of the sensation it creates in the human ear. The measurement of sound intensity is sometimes expressed in watts per centimeter. An instrument used to measure the loudness of sound accurately is a sound level meter. We find the loudness of a sound depends on two factors. The amplitude of vibration of the source which determines the amplitude of the sound produced and the distance between the source and the ear or measuring instrument. An example of this last statement is; the harder a drum is hit the louder the sound or the longer the amplitude of the vibration. Recognize also the further away you stand from the drum the weaker the sound is. Another way we can express the loudness of a sound is by saying; the amplitude of a vibration depends on the amount of energy imparted.

c. Timbre of Sound. The third characteristic of sound is called timbre, sometimes called quality, is vital to the recognition of sounds and voices. A note played on a violin is recognized as coming from a violin; a note coming from a flute is recognized as coming from that instrument because of the particular combination of harmonics contained in the sound as previously explained. The rest depends on the frequencies and intensities of the harmonics of the sound, relative to the fundamental frequencies. A particularly pleasing voice or sound is generally rich in overtones. To any individual, the timbre or quality of a particular sound may or may not be pleasant, but the quality helps to identify the object, instrument or person that is its source.

9. Characteristics of Speech.

a. Human speech contains all of the basic characteristics of sound plus some peculiarities of its own. The vocal cords are the source in the production of most vocal sounds. They are vibrated by a stream of air from the lungs being forced between them. The pitch of a violin is determined by varying the length and thickness of its strings. The range and pitch of the voice is determined in much the same way. The vocal cords become shorter and thicker or longer and thinner while speaking. The amount of air (power) furnished by the lungs determines the loudness of volume of the sound produced. You can recognize the difference in the amount of effort required between a shout and a whisper. The action of the lungs when generating power is similar to the compressive action required to play an accordian.

b. The throat, mouth, and nasal passages contribute to the quality of the sound produced by the voice. The size and shape of the vocal passage is varied by the size and shape of the tongue, palate, lips, and jaw which determines the number and proportions of the various harmonic frequencies in the resulting sound. The upper nasal cavity and the bone structure of the head also have an effect on the timbre of the voice. The effect from the actions of these organs can be compared to the various sizes, shapes, and materials, and these effects on the quality/timbre of the musical sounds produced by various wind instruments.

10. Inflection.

Inflection is a small variation in pitch or loudness which a speaker uses to place emphasis or special meaning on his words. The inflection,

given to the human voice in speaking indicates to a great extent the thought and significance of what is said. Inflection is also the use of pauses of varying length for giving meanings. Therefore, different inflections are used for commands, questions or statements of fact and express attitudes, feelings and emotions. Inflection is an important factor in determining the intelligibility of a spoken word or phrase, therefore persons who use devices or equipment for the transmission of speech--telephones and microphones--must be conscious of their speech habits. They must concentrate on correctly shaping the tones so that as much meaning as possible is transmitted to the listener. Vowel sounds must be made with the proper amount of mouth opening, and consonants must be formed by the correct placement of tongue and lips.

11. Frequency Range of Voice Sounds.

a. The frequency range of the voice is one of the most important factors affecting the design and construction of telephone lines and equipment. Figure 6 illustrates the frequency range of the piano keyboard, together with the ranges of the voices of men and women and those of a number of musical instruments. The sounds of a normal speaking voice contain fundamental frequencies between 100 and 300 hertz. The overtones contained in these sounds extend the range of frequencies to approximately 5,000 hertz. Voices of different individuals vary in their frequency content. Men usually have voices with lower fundamental and harmonic frequencies than those of women and children. The range of fundamental frequencies of the singing voice is greater than that of the speaking voice; it varies from about 80 hertz for a deep bass to about 1,200 hertz for a high soprano. The overtones contained in the sounds of the singing voice reach as high as 10,000 hertz. For purposes of comparison, the frequency range of the instruments of a symphony orchestra includes fundamental of about 16 to 4,000 hertz with overtones ranging to 12,000 hertz or higher.

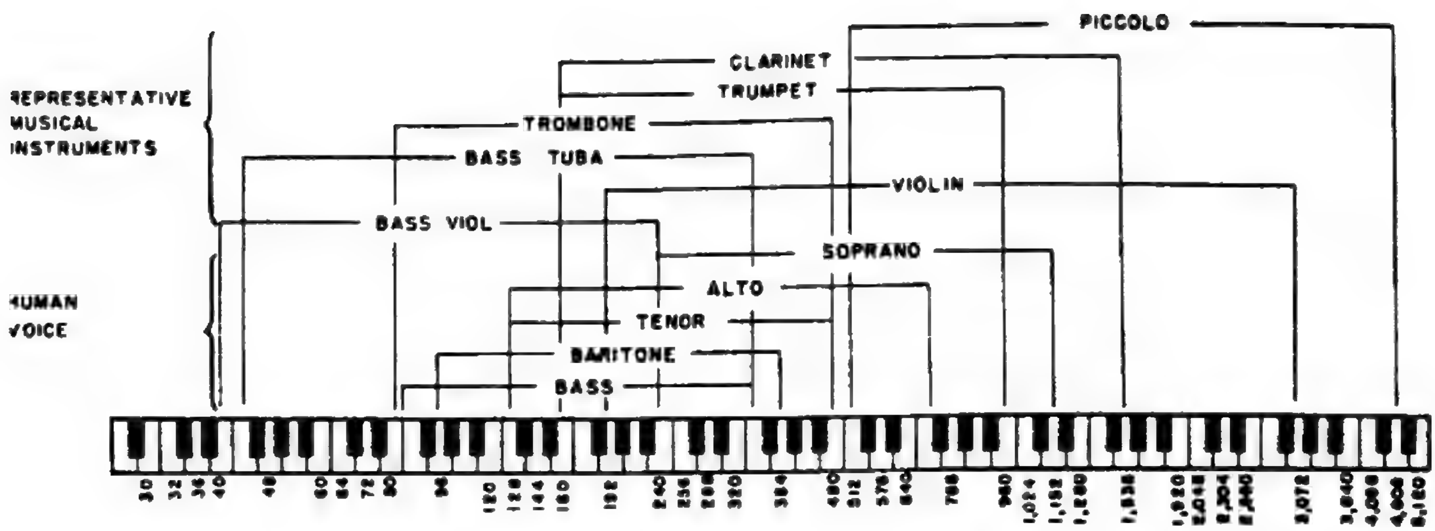

FIGURE 6. Fundamental Frequency Ranges of Instruments and Voices

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b. Because of the greater range of frequencies contained in musical sounds--voice and instrument--telephone circuits designed for their transmission must have more rigid specifications to prevent distortion. This increases both the initial cost of the equipment and the expense of maintaining it. For transmission or ordinary conversation, however, it has been found that a sufficiently high degree of intelligibility can be achieved if the frequencies transmitted are limited to those between approximately 200 and 2,700 Hertz. This is the range of frequencies with which the various circuits and equipment to be discussed in this manual are concerned.

12. Sound Power.

The power contained in the sounds of speech depends on the power furnished by the lungs. It varies considerably during ordinary conversation, with the inflections given to the voice. The average power contained in speech at a normal conversational level is about 1/100,000 watt, or 10 microwatts. By comparison, the average power of speech conducted as loudly as possible is about 1,000 microwatts. Words spoken in as weak a voice as possible, without whispering, have an average power of about 1/10 microwatt; words whispered may have an average power as low as 1/1000 microwatt. In ordinary speech, the vowels contribute the greatest power, reaching a maximum of about 2,000 microwatts. The power of speech in sounds is an important factor in the design and operation of telephone equipment, because the equipment must be able to respond to the differences in power delivered by the voice.

13. Hearing.

a. Hearing is the perception of sound by the brain. It involves the response of the ear to sound waves, the transmission of impulses through nerves to the brain, and perception by the brain of the transmitted intelligence. There is a measurable variation among individuals in the ability to hear, since hearing for a given person depends on the loudness and pitch of the sound. An approximate determination of hearing ability in terms of loudness only can be made by measuring the maximum distance at which the ticking of a watch can be heard. A more complete and accurate method involves the use of a device called an audiometer. The audiometer enables an experienced operator to construct a scientific graph of the hearing ability of an individual. This graph then may be compared to what generally is accepted as normal hearing ability. The audiometer consists of a calibrated audio oscillator, the frequency and amplitude of which may be varied, and a telephone receiver for the reproduction of sound waves. The frequency can be varied from 0 cycle to about 25,000 hertz per second, and the amplitude can be adjusted to make the intensity of the sound (loudness) vary through a wide range.

b. In conducting a test with the audiometer, the instrument first is adjusted to any chosen frequency--for example, 1,000 hertz--then, at that frequency, adjusted to an amplitude so low that the sound from the receiver is inaudible. The amplitude then is increased gradually until a point is reached where the sound becomes just perceptible to the ear of the person being tested. This point is called the threshold of audibility for that frequency. For any given frequency it is the lowest intensity at which sound is audible. In the normal ear, the threshold of audibility varies with the frequency of sound, so that its ability to hear some frequencies is greater than the ability to hear others. In addition to this variation, the threshold of audibility for different frequencies is different for different individuals. For these reasons, a number of frequencies are tested in the measurement of hearing with an audiometer. The lower curve of figure 7 shows how the average, or normal, threshold of audibility varies with sound frequency. The dip in the lower curve indicates that the average ear is most sensitive to frequencies in the vicinity

of 2,000 hertz. As a person grows older the ability to hear sounds at higher frequencies diminishes.

c. As the amplitude of a sound wave is increased the sound becomes louder until a point is reached where the sound is no longer heard. The body continues to feel the vibrations; however, if the amplitude is increased still further, a point is reached where there is a sensation of pain. This point is called the threshold of feeling, and it also varies with frequency and with the individual. The upper curve of figure 7 shows the threshold of feeling of the average person and how it varies with frequency.

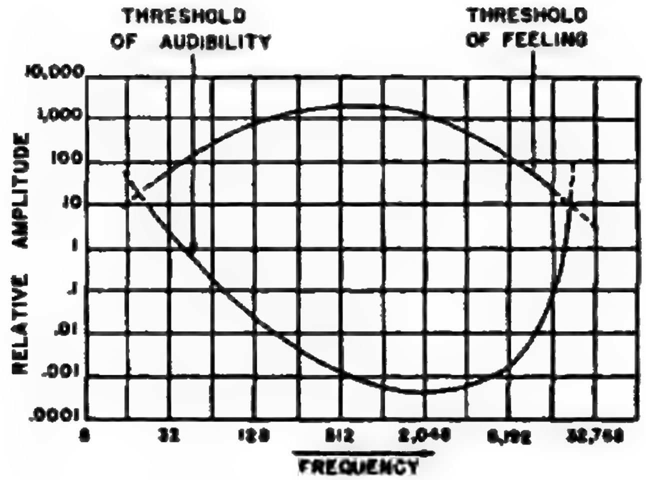


FIGURE 7. Curves of Normal Hearing Ability.

14. Face-to-Face Conversation.

A statement of the larger factor involved in face-to-face conversation will prove of value in helping the reader to grasp the more complex problems encountered in the transmission of sound over telephone wires. In face-to-face conversation the speech sounds of one person are transmitted to the ears of another by means of the intervening air. The distance between the individuals usually is small, so that there is very little loss (attenuation) of power in the transmission process, and the speaker may keep their voices at a normal conversation level. One is accustomed to the way the voice of an acquaintance sounds during face-to-face conversation, and hears in the voice what one feels is complete "naturalness" of tone and quality. (One even hears in one's own voice what is thought to be complete naturalness of tone and quality, although one becomes surprised at the difference when a voice recording is heard.) Also in face-to-face conversation additional meanings are received from the facial expressions and gestures which accompany the spoken words. This is an important factor, especially for the many people who are hard of

hearing, for it aids in the comprehension of the ideas being transmitted. It also helps any listener to concentrate on conversations taking place amid sources of distraction, such as other conversations or unusual noise.

15. Conversation by Telephone.

The relatively low power of speech sounds limits the maximum distance over which individuals may conduct face-to-face conversation. An attempt to converse at greater distances usually results in a lower degree of intelligibility. For communication over greater distances, some other means of transmitting the voice is required, and the telephone is the simplest device for this purpose. However, although the telephone succeeds in performing this primary function, its operation presents some rather complex problems which do not occur in transmission of sound through air. These problems include distortion of the sound, noise generated mechanically and electrically in the telephone system, noise from external sources, the cutting off of some of the low and high-frequency components of the sound, and the reduction in volume (attenuation) which occurs in long-distance transmission. All of these problems tend to reduce the intelligibility of the words, the naturalness of the tone, and quality of the sound. They arise from the wires, from the component parts of the equipment, and from the associated circuits required for the generation of power. The engineer must take account of these problems in designing telephone equipment, and both the operator and the maintenance man must be familiar with them to secure the best possible operation of the equipment. Particularly, distortion of sound and distraction from external sources must be kept at a minimum since personal contact, so important in face-to-face conversation, is lacking.

16. Summary.

a. Sound waves are caused by the vibration of a rigid or semirigid body.

b. The transmission of sound always requires a medium; the transmission of light or electromagnetic waves does not require a medium. Air is usually the medium for sound transmission, but either liquid or solid mediums can be used.

c. Vibrating bodies set up alternate condensations and rarefactions in adjacent groups of air particles. These particles transfer their motion in turn to the next group, and this continuing action produces a wave of energy.

d. A hertz (cycle) is a complete set of pressure values, from one positive peak to the next, anywhere along the path of the wave. The maximum pressure value, measured from the zero axis, is called the amplitude of the wave.

e. Wavelength is the actual distance between successive condensations or successive rarefactions along the path of the sound.

f. The time required for 1 hertz is called the period of the wave.

g. Frequency is the number of hertz per second.

h. The velocity of a sound wave is the distance the energy travels in a unit of time, usually expressed as feet per second. The velocity of sound in air is 1,090 feet per second at 0° C, and 1,130 feet per second at 20° C. By comparison, light and electromagnetic waves travel at a velocity of 186,000 miles per second.

i. The wavelength of a sound wave can be calculated by the following relationship:

$$\text{wavelength} = \frac{\text{velocity}}{\text{frequency}}$$

j. The frequency range of audible sound is approximately 20 to 20,000 hertz per second.

k. In air and at a velocity of 1,100 feet per second, the wavelength of the audible frequencies ranges from 55 feet to approximately two-thirds of an inch.

l. Sound waves must be simple or complex. A simple sound wave is a wave made up of a single frequency varying sinusoidally. A complex sound wave is one made up of more than one frequency.

m. The lowest frequency present in a complex waveform is called the fundamental frequency. Whole-number multiples of the fundamental frequency of a sound wave are called harmonics or overtones. The fifth harmonic of a 1,000-hertz sound is 5,000 hertz.

n. Pitch is the relative frequency of a sound. Loudness or volume is the relative amplitude of the wave producing a sound.

o. Quality or timbre is that characteristic of a sound which makes it recognizable as a certain kind of sound. Quality depends on the number of harmonics present and on the relationship between the fundamental and its harmonics.

p. A musical tone is a complex but regular waveform rich in harmonics; noise is a complex but irregular waveform.

q. Human speech is characterized by its quality, inflection, and range. Inflection is the small variation in pitch or loudness which a speaker uses to place emphasis or special meaning on his words.

r. The sounds of the normal speaking voice are at fundamental frequencies between 100 and 300 hertz. The overtones contained in these sounds extend the voice range of frequencies to approximately 5,000 hertz.

s. The range of fundamental frequencies of the singing voice varies from about 80 hertz to 1,200 hertz; the overtones reach as high as 10,000 hertz.

t. The range of fundamental frequencies of a symphony orchestra varies from about 16 to 4,000 hertz, with overtones to 12,000 hertz or higher.

u. Most telephones are limited in frequency response to the range from 200 to 2,700 hertz.

v. Speech transmitted by telephone introduces some distortion, noise, and frequency limitation, causing loss in intelligibility, naturalness, and quality.

w. The average power contained in speech at a normal conversational level is about 10 microwatts; at the loudest level it is about 1,000 microwatts; at the weakest level it is 1/10 of a microwatt; at a whisper it is about 1/1,000 of a microwatt.

x. For any given frequency, the threshold of audibility is the lowest intensity at which sound is audible, the threshold of feeling being the lowest intensity causing a sensation of pain.

CHAPTER 2

TRANSMITTERS AND RECEIVERS

17. Introduction to Telephony.

a. Historical background of telephone.

(1) The combination of principles on which the operation of the telephone is based was discovered in 1875 by Alexander Graham Bell. At once, Bell started a series of experiments to perfect practical instruments for the transmission of sound over wires. After 9 months, the first complete sentence was transmitted, over an indoor line extending a distance of about 150 feet. By 1877, an outdoor line from Boston to Cambridge, a distance of about 2 miles, was in use. The early instruments were crude and not too effective. They operated on the principle that a diaphragm, vibrating in a magnetic field, can induce an electric current in a wire. The same device was used as both transmitter and receiver. The strongest magnets and best diaphragms then available would not permit transmissions over long distances.

(2) One year after the invention of the original telephone, however, the perfection of the Blake transmitter operating on the principle that the vibration of a diaphragm can vary the strength of an already existing electric current was completed. Immediately, the problem was presented of establishing a means to connect the lines of different subscribers, whenever they wished to talk. This problem was overcome in 1878 with the opening of the first central office, or exchange, in New Haven. By 1900, means were evolved for the telephone user and exchange to signal (ring) each other when calls were to be initiated or completed. Present-day telephone systems provide vast improvements over those of earlier design and construction in the distances over which satisfactory transmission can be accomplished, dependability of established plant facilities, and the quality of the reproduced signals.

b. Basic functions of telephone system.

(1) By means of the telephone, conversations may be held over great distances. To accomplish this, the sound waves of speech must be converted into a form of energy that can be transmitted efficiently over wires. The conversation is effected by electrical waves (current) in the transmitter of the speaker's telephone set. There, electrical waves are created which correspond to sound waves both in waveform and frequency. The electrical waves are

transmitted over the wire, or transmission line, and enter the receiver of the listener's telephone set. The receiver converts the electrical waves back into sound waves which, again, correspond in waveform and frequency to the original sound waves. The listener in his receiver thus hears words corresponding to those spoken into the distant transmitter.

(2) This process is shown in block form in figure 8. Above, on each side, is a graph of the sound waves as spoken and heard. The electrical wave is shown in the center.

(3) The fundamental principle of the telephone can be summarized by the explanation that electrical waves, traveling over wires, are substituted for sound waves, traveling in air, over the major portion of the distance separating the speaker and listener. Various types of telephone systems are in use, but this underlying principle is common to them all.

18. Telephone Transmitter.

a. Function of telephone transmitter. The function of the telephone transmitter is to convert waves of sound into waves of electric current of corresponding waveform and frequency. The energy of the waves of electric current so generated must travel over wires for relatively long distances, and arrive at the receiver at a level providing normal listening. But energy is lost in transmission over wires. Because of this loss, the initial energy of the electrical waves must be made greater than the original energy of the sound waves. The circuit of the transmitter therefore must provide a means of supplying this extra energy to the electric waves which it generates.

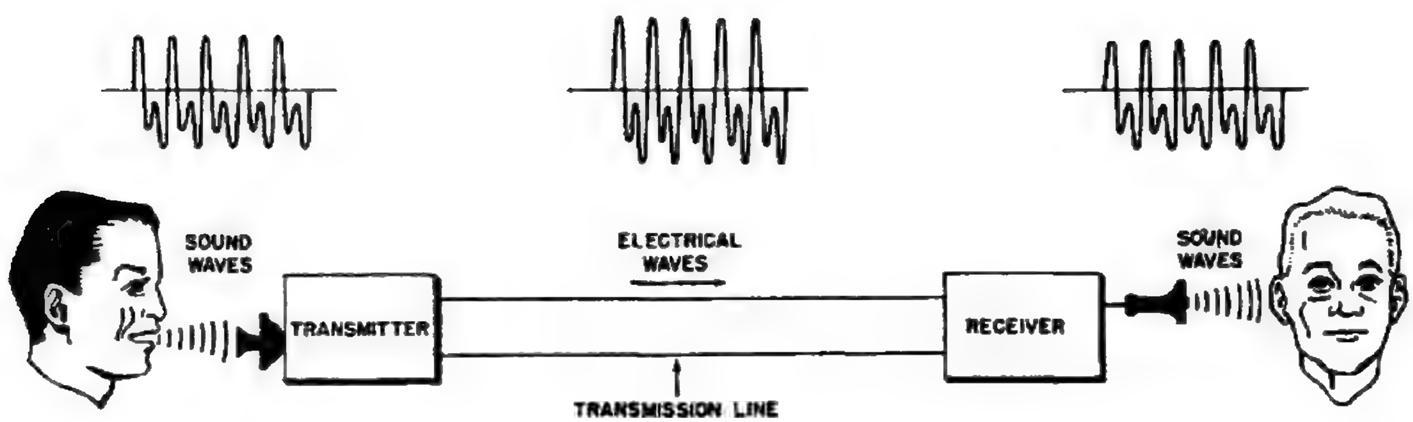


FIGURE 8. Transmission of Sound by Telephone.

b. Telephone transmitters.

(1) Paragraph 17a(1) describes the principle of operation of the earliest type of instrument used as a transmitter. This type of transmitter had a coiled wire wound around one pole of a permanent magnet, and a thin metal wafer of magnetic material, called the diaphragm, mounted adjacent and at right angles to the magnet. Sound waves colliding with the diaphragm would cause it to vibrate at a frequency determined by the frequency of the condensations and rarefactions of the air molecules, as illustrated in figure 3. It will be understood that the intensity of these condensations and rarefactions vary with each change in characteristic among the various sound waves, and that the amplitude of each diaphragm motion also will be affected by the same conditions; accordingly, the frequency and the amplitude of the diaphragm vibrations will cause the density of the magnetic field, in which it is located, to change with each change of position of the diaphragm. Since this varying magnetic field is cutting across the coiled wire, a voltage is induced in the wire. The voltage thus induced is alternating, since all induced voltages are alternating voltages.

(2) If two wires now are connected to the coiled wire ends and their extremities are connected in turn to another instrument similar in construction to that described (1) above, the induced ac voltage will cause a variation in the strength of the associated permanent magnet, and, since the strength of the permanent magnet field determines the instantaneous position of the diaphragm, each change in current intensity and direction of flow will cause a change in the position of the diaphragm. Because these changes are at the same frequency as those of the diaphragm at the originating point, the diaphragm at the terminating point will reproduce the same waves established originally.

(3) This entire process encompasses the changing of sound energy into electric energy, transmitting the signals electrically and then reconverting the electric energy into sound energy.

(4) The distance of which this process can be applied usefully is quite limited, since no provisions are made for amplifying the original energy provided by the sound waves present at the originating end. If all of this energy could be reserved for operating the diaphragm at the distant end, the distance between telephones could be extended almost indefinitely; however, this cannot be so, because part of the original energy is used in over coming

the inertia of the adjacent diaphragm; there are, also, further energy losses in the connecting wire, in the coils at both ends of the connections, in the two permanent magnets, and again in overcoming the inertia of the diaphragm at the distant end. The useful energy then is that which appears as sound at the distant end and it can be only the original energy minus all the energy losses.

(5) The only source of power furnished the instruments discussed above is that supplied by the person speaking, assuming speech transmission. Such transmission thus is said to be accomplished by use of a sound-powered transmitter, which is discussed further in Lesson 3 Chapter 6. As a matter of interest, such a transmitter actually is used in present-day communications as a receiver. As explained in paragraph 12, the average power contained in speech at a normal conversational level is about 10 microwatts. It is this power limitation, plus the lack of amplifying facilities, that limits the distances over which such instrumentalities can provide satisfactory sound transmission.

(6) The transmission limitations of the sound-powered transmitter were overcome with the advent of the carbon transmitter, the operating principles of which are described below.

19. Carbon Transmitter.

a. Operating principle of carbon transmitter.

(1) The operating principle of the carbon transmitter can be explained with the help of the simplified circuit shown in figure 9. The circuit consists of battery B and variable resistance R which represents the variable resistance of the carbon granules. Assume that the battery has an emf (electromotive force) of 6 volts, and that R may be varied from 0 to 1000 ohms, with a normal setting of 300 ohms. The normal or average value of current I that flows is 6 volts divided by 300 ohms, or 20 ma (milliamperes). If the resistance, R, is reduced to

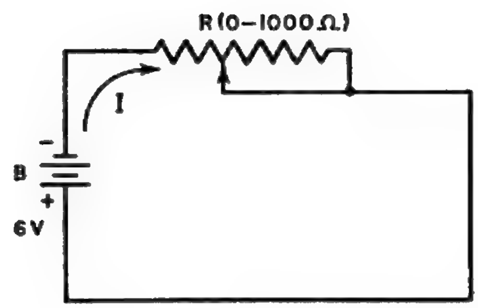


FIGURE 9. Equivalent Circuit of Carbon Transmitter

240 ohms, the current increases to 25 ma, and if the resistance is reduced further to 200 ohms, the current increases to 30 ma. Similarly, if is increased to 400 ohms, the current decreases to 15 ma, and if is increased further to 600 ohms, the current decreases to 10 ma. If the resistance is varied continuously about its normal value of 300 ohms in a certain manner, the variations of current about its average value of 20 ma can be tabulated as follows:

Time (milliseconds)	Resistance (ohms)	Current (milliamperes)
0...........................	300	20.0
1/3.........................	240	25.0
2/3.........................	209	28.7
1...........................	200	30.0
1 1/3.......................	209	28.7
1 2/3.......................	240	25.0
2...........................	300	20.0
2 1/3.......................	400	15.0
2 2/3.......................	531	11.3
3...........................	600	10.0
3 1/3.......................	531	11.3
3 2/3.......................	400	15.0
4...........................	300	20.0

(2) Figure 10 shows the graph of current versus time constructed from this tabulation. The current waveshape is one of pulsating direct current. This consists of an ac (alternating-current) wave superimposed on a dc (direct-current), or average, value of current. The dc component is 20 ma, and the ac component is a sine wave with an amplitude of 10 ma. The period of the wave, or the time for 1 cycle, is 4 milliseconds, or .004 second. The frequency of the wave can be calculated by using the formula:

$$f = \frac{1}{\text{period}}$$

$$f = \frac{1}{.004} = 250 \text{ cycles.}$$

The rate at which the current varies about its average value depends on the rate at which the resistance is varied about its normal value.

b. Application of operating principle to carbon transmitter. A, figure 11, illustrates the operation of the carbon transmitter, the principle of which is based on the simplified circuit in figure 11. The basic circuit components are battery, B, a cup of carbon granules, C, metal diaphragm, D, and an induction coil. The negative terminal of the battery is connected to a small carbon disk which is fastened rigidly to the diaphragm. This disk rests against one side of the cup of carbon granules; the other side of the cup is connected to one end of the primary of the induction coil. The circuit is completed by the return of the primary to the positive terminal of the battery.

(1) When no sound waves strike the diaphragm it remains stationary, the resistance of the carbon granules remains constant, and, as a result, a steady direct current flows through the circuit (A, fig. 11). The value of this current depends on the combined resistance of the carbon granules and the dc resistance of the primary of the induction coil. Since an induction coil is, in effect, a transformer, no emf is induced in the secondary when steady direct current flows in the primary. Therefore, when no sound energy is transferred to the diaphragm (that is, when the diaphragm does not move), no current flows in the secondary of the induction coil. The normal resistance of an actual new transmitter unit is approximately 35 ohms; the dc resistance of the primary of the induction coil varies with the type of coil used. These coils will be discussed more completely in a later chapter.

(2) When sound waves strike the diaphragm, it vibrates in accordance with the variations of intensity and frequency of the waves (A, fig. 11). This vibration causes a varying pressure to be exerted on the carbon granules, which changes their state of compression. As the compression increases, the resistance of the granules decreases, causing the current in the circuit to increase. As the compression decreases, the resistance of the granules increases, causing the current to decrease. Because the amplitude and frequency of the current vary directly as the amount and rate of change of the compression of the carbon granules, they vary as the amount and rate of change of the pressure exerted on the diaphragm, and, therefore, vary as the intensity and frequency of the sound waves which strike the diaphragm. The varying current is a pulsating direct current. (Figure 12 shows such a current, resulting from a simple wave. The ac component of a current resulting from speech is, of course, a complex wave, but again it is superimposed on a direct current to form a pulsating direct current.) Because the emf induced in the

secondary (A, fig. 11) depends only on the varying component of the current in the primary, an alternating emf is induced in the secondary. When a load, such as a meter or receiver, is connected to the secondary, and alternating current flows in the secondary circuit.

20. Structure of Carbon Transmitter.

a. B, figure 11, shows the front view and a cross-sectional side view of a carbon transmitter. This unit is one of several types in common use, all with a similar basic structure. The path of current within the unit is from the moving electrode, which is fastened to the diaphragm, through the carbon granules, to the back electrode. A bell-shaped carbon chamber is used so that there is sufficient contact between the carbon granules and the electrodes. Since the contact is uniform, and operation is equally good in whatever position the transmitter is held, this is called a nonpositional transmitter. The moving front electrode exerts varying pressure on the granules in accordance with the vibration of the diaphragm, and the transmitter consequently is of direct-action type. As the diagram shows, the moving electrode is attached to the center of the conical diaphragm, and forms the front center surface of the carbon chamber.

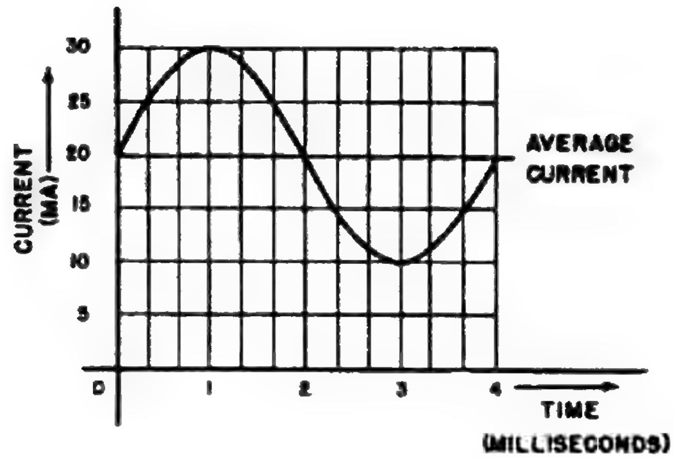
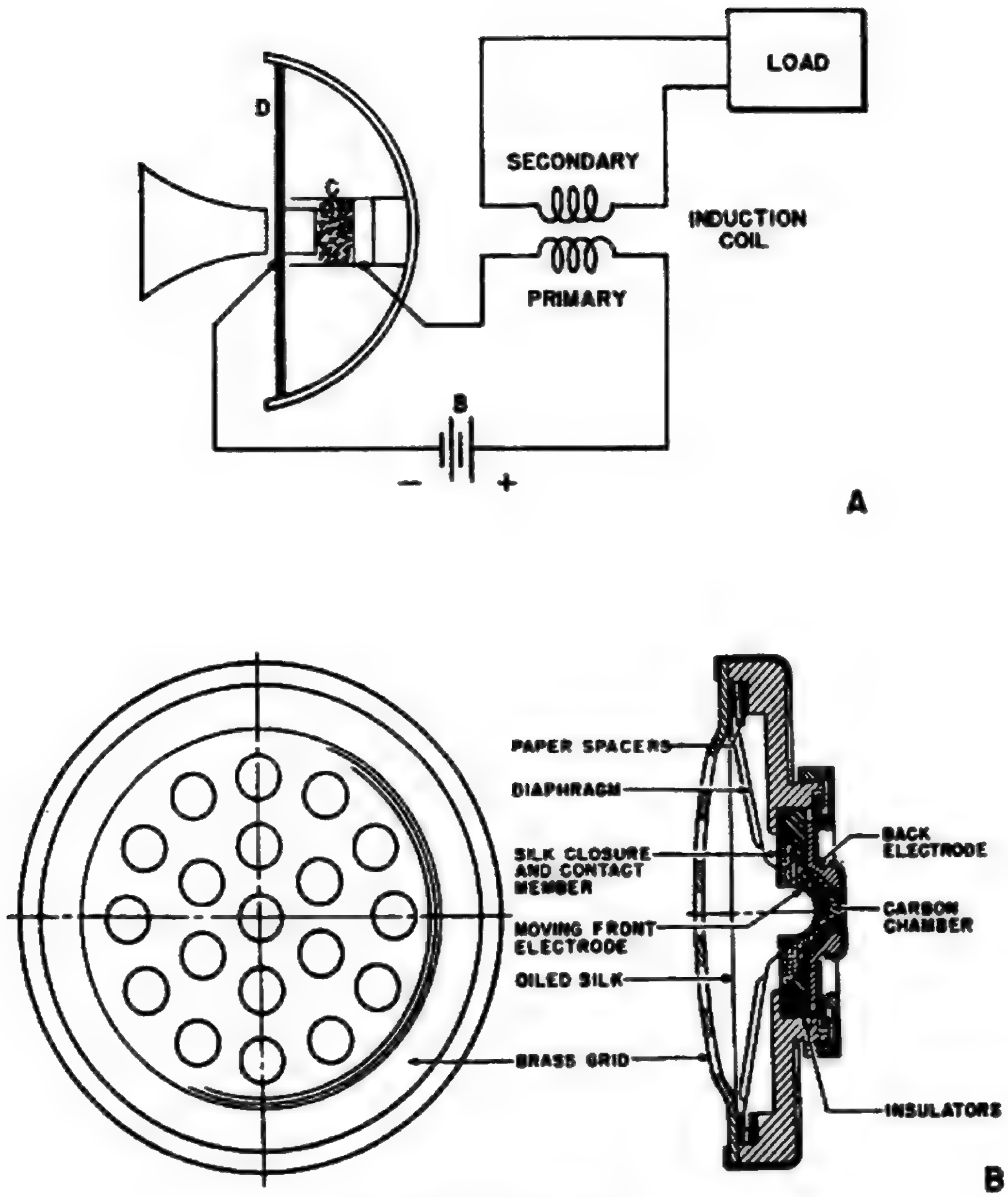


FIGURE 10. Current Versus Time

b. The diaphragm is made of an aluminum alloy (B, fig. 11). Its thickness is .003 inch, and it has radial ridges to increase its stiffness. Paper spacers, consisting of a number of thin paper rings, support the diaphragm at its edge without interfering with its movement. The carbon chamber is closed on the front side by a silk covering, clamped on the flange of the front electrode. A light, spoked, copper contact member, clamped under the front electrode, provides a flexible connection between the front electrode and the metal frame. The stationary back electrode is held in place in the frame by a threaded ring, and is insulated from the frame by a fiber washer and a ceramic



A. Circuit. B. Structure.

FIGURE 11. Carbon Transmitter

insulator, which also forms part of the rear surface of the carbon chamber. The surfaces of both front and back electrodes are gold-plated where they make contact with the carbon granules. The perforated brass grid protects the vibrating parts from mechanical injury. The working parts are kept free from moisture by an oiled-silk membrane stretched between the brass grid and the diaphragm.

c. The transmitter unit is mounted in a handset, as shown in the disassembled view of figure 20. It is held in place by the transmitter cap, along with contact springs which press against its contact. The unit may be removed for servicing by unscrewing the plastic cap or mouthpiece.

d. An improved type of carbon transmitter is shown in figure 12. The frequency response of this unit has been improved by use of an acoustic network which couples the back chamber of the diaphragm through an acoustic resistance to the cup chamber. Woven rayon fabric is used for the acoustic resistance material. This transmitter, in addition to an improved frequency response, has a high modulation efficiency. Note that the diaphragm of this transmitter is clamped rigidly at its outer edge, whereas the diaphragm of the element in B, figure 11, is floated between paper spacers.

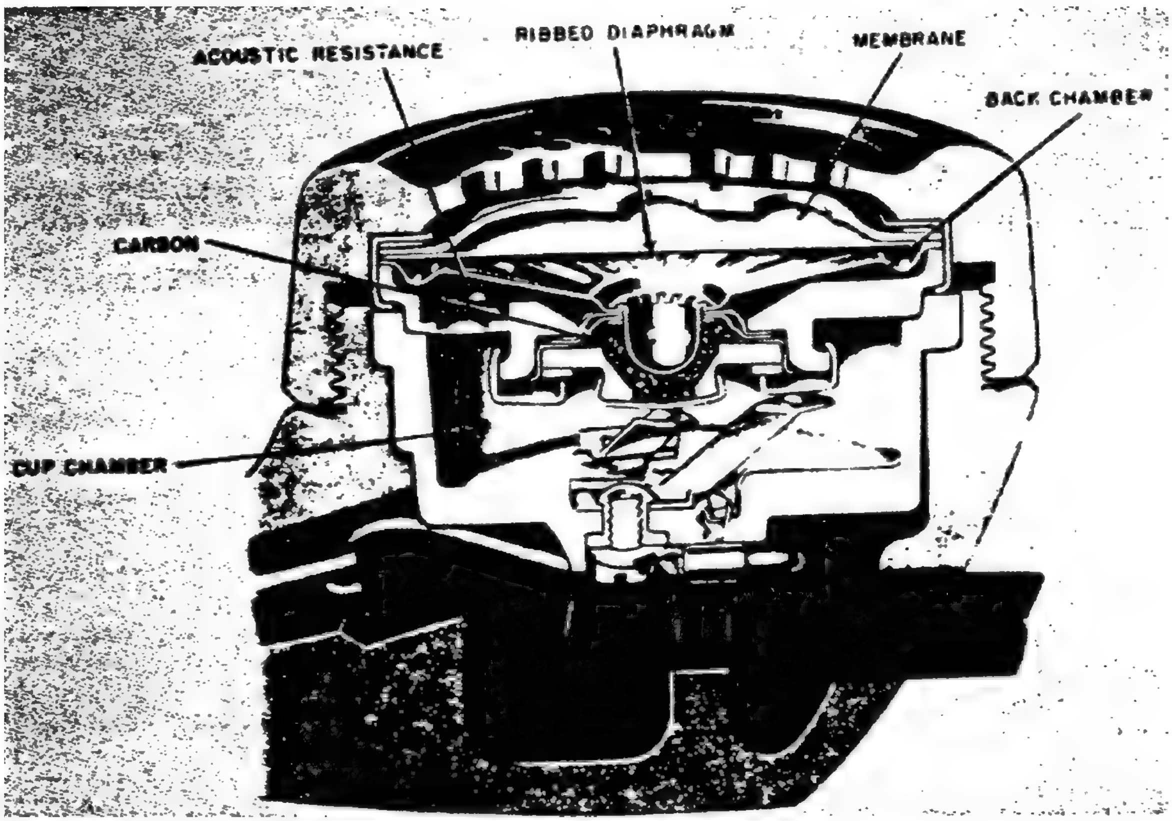


FIGURE 12. Modern Transmitter

21. Noise-Canceling Transmitter.

a. The transmitter shown in B, figure 11 has a major disadvantage in that it is susceptible to interference from noise. This disadvantage is most noticeable when the transmitter is operated in places where the noise level is high, such as near railroad trains, airfields, the interior of tanks, and areas where gunfire or bombardment is taking place.

b. A number of transmitters have been developed which reduce interference from noise sources. Among these are the throat transmitter and various kinds of directional transmitters, which restrict the movements of the operator and produce some distortion of his speech. Recently, however, a transmitter has been developed which largely eliminates noise interference without restricting movement. It is called a noise-canceling or differential transmitter.

c. The United States Army Type T-45 lip transmitter (fig. 13) is an example of this type. In operation, sound waves activate its diaphragm only if they are introduced close and perpendicular to the front surface of the diaphragm. Sounds which originate at some distance enter the transmitter through two openings, on the front and back of the diaphragm. Since this equalizes the pressure exerted on both faces, the resultant motion of the diaphragm for distant sounds is practically zero. There is almost no change in the resistance of the carbon granules and, therefore, almost no change in current as a result of these sounds. Since, in responding to distant sounds, the diaphragm neutralizes pressures of relatively low frequencies more than those of high frequencies, the noises most canceled are those originating in tanks and from gunfire, mainly in the low-frequency range. By proper design, it is possible to make the cancellation of noise practically complete. This feature makes the differential transmitter much more suitable than others for many military applications, and also makes it valuable for many civilian uses.

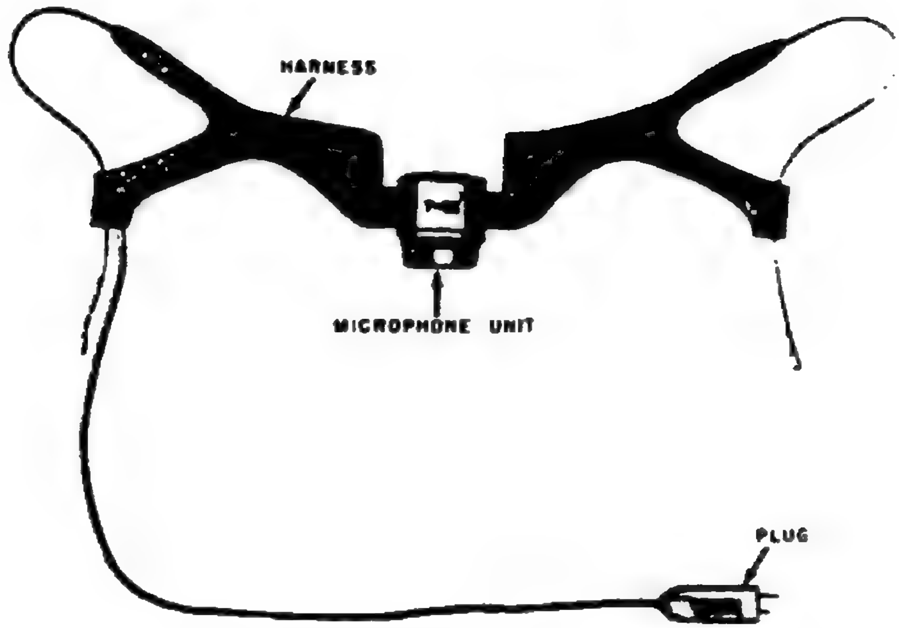


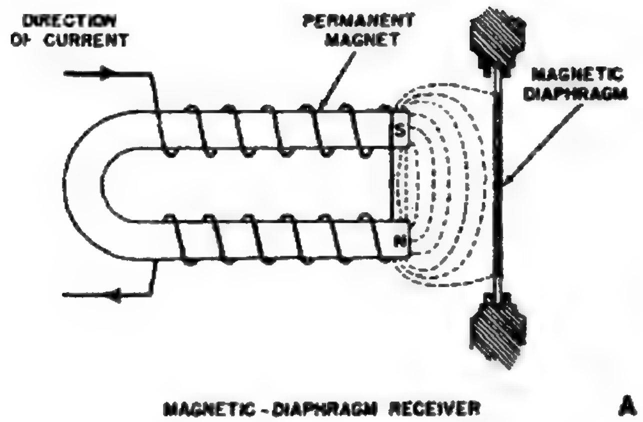
FIGURE 13. U.S. Army Type T-45 Lip Transmitter

22. Telephone Receivers.

a. Function of telephone receiver. The function of the telephone receiver is to reproduce the sound made in the transmitter at the other end of the transmission line. It is accomplished by reconverting to sound waves the electrical waves transmitted to it. The function of the receiver, therefore, is the reverse of that of the transmitter. The receiver also must prevent leakage of sound. This requirement is satisfied by the construction of the earpiece, which is designed to be held close to the ear.

b. Types of telephone receivers. According to their means for converting electrical waves to sound waves, telephone receivers may be either magnetic-diaphragm or moving-conductor types.

(1) The magnetic-diaphragm receiver (A, fig. 14) contains a permanent magnet, and operates by variation of the strength of its magnetic field. The amplitude and frequency of the variation of the magnetic field cause a corresponding variation of the motion of the magnetic diaphragm. This is the receiver most commonly used in telephone communications.



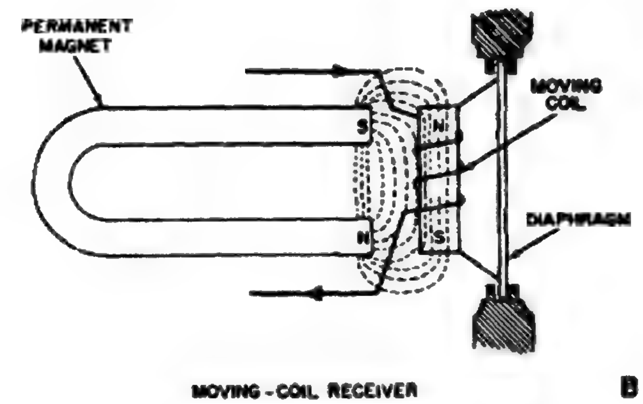


FIGURE 14. Comparison of Operating Principles of Two Receivers

(2) The moving-conductor receiver, shown in B, also contains a permanent magnet, but it operates on the principle of the electrical meter. The moving conductor is usually a coil or ribbon of aluminum alloy, attached to the diaphragm. As the current in the coil varies, the magnet field around the coil varies. This varying field reacts with the field of the permanent magnet, causing the coil to vibrate. The vibrations of the coil are transferred to the diaphragm, which generates sound waves of the same frequency and waveform characteristics as the current in the coil. The moving-conductor receiver is also called the moving-coil receiver and the dynamic receiver. The dynamic loudspeaker used in radio receivers is similar to it in action.

23. Magnet-Diaphragm Receiver.

a. Operating principle of magnetic-diaphragm receiver. The operating principle of the magnet-diaphragm receiver (fig. 15) is based on an elementary principle of magnetism--the ability of a magnet to induce a magnetic field of opposite polarity in a magnetic material placed near it. Because the induced polarity is opposite, attraction always results between the magnet and the material. For example, a magnet and an iron nail are attracted to each other.

(1) When a magnetic diaphragm is placed near the bar magnet, as in A, and its range of motion is limited suitably, it will be attracted to the magnet without actually touching it. The magnet exerts a permanent pull on the diaphragm. If a coil is wound around the magnet as in B, C, and D, and current is caused to flow in the coil, the pull on the diaphragm will be increased or decreased, depending on the direction and magnitude of the current. If the current in the coil is a sinewave alternating current, it varies the strength of the magnetic field accordingly.

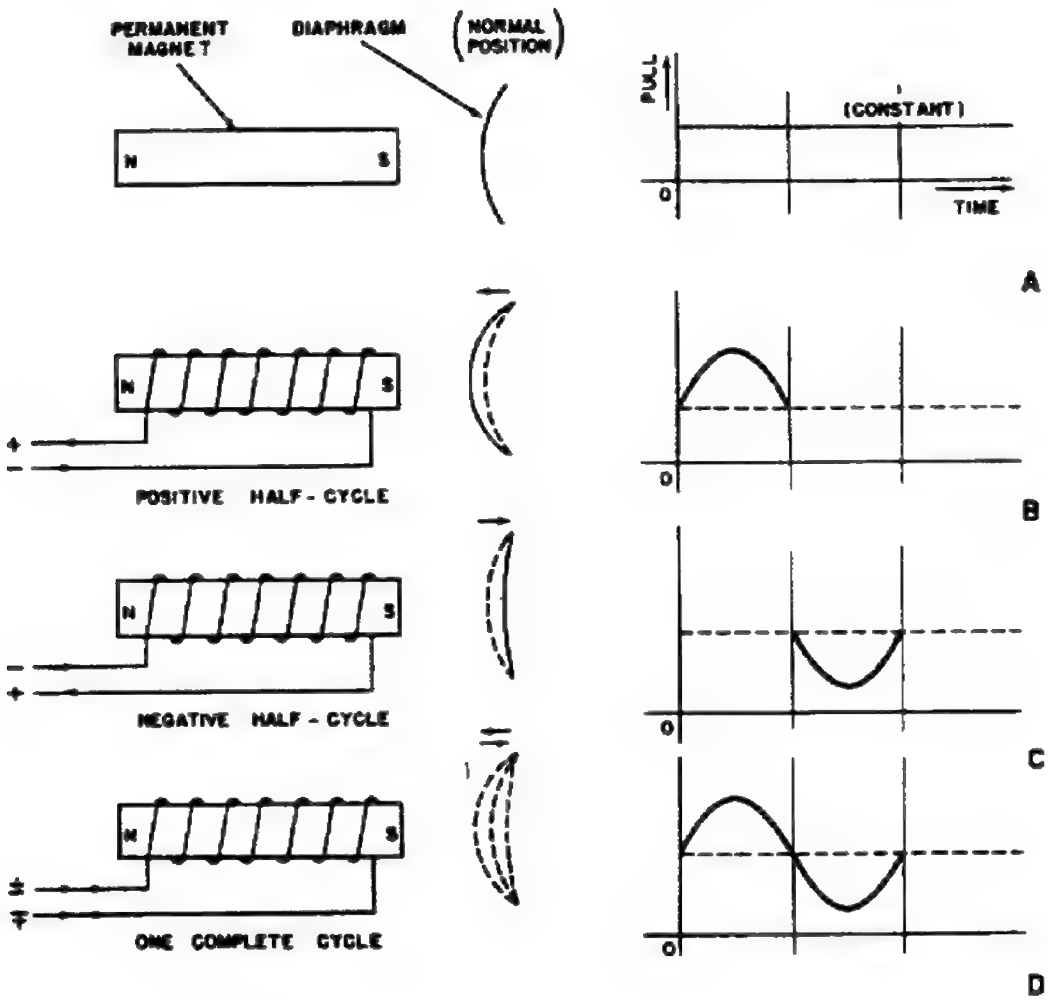


FIGURE 15. Operation of Magnetic Diaphragm Receiver

During the positive half-cycle of such current, shown in B, as the current varies from 0 to maximum and back to 0, the strength of the magnetic field varies from its original value to maximum and back to its original value. The pull on the diaphragm at the same time varies from its normal value to maximum and back to its normal value. During the negative half-cycle in C, as the current varies from 0 to maximum in the opposite direction and back to 0, the strength of the magnetic field varies from its original value to minimum (because of the reversed direction of current) and back to its original value. The pull on the diaphragm at the same time varies from its normal value to minimum and back to its normal value. These actions in sequence cause a vibration of the diaphragm. The vibration is actually a sinusodial displacement of the diaphragm about a normal, or neutral, position, shown in D. A series of vibrations results in the generation of a series of sound waves of corresponding frequency and waveform. Figure 16 shows comparative graphs of the sound-wave input at the transmitter, the current in the transmitter, the magnetic pull on the diaphragm, and the sound-wave output at the receiver.

(2) Figure 17 illustrates the reason for using a permanent magnet in the telephone receiver. The permanent magnet is replaced by an electromagnet, with a coil wound on a soft-iron core. When no current flows in the coil, there is no magnetic field; therefore the diaphragm remains in its neutral position, as in A. When a sinusodial current flows in the coil during the positive half-cycle, a magnetic field of similar variations is produced, as in B, and this field attracts the diaphragm so that its motion corresponds to the variation of the field. During the negative half-cycle, in C, the polarity of the magnetic field is reversed, but the displacement of the diaphragm is exactly as before, since only attraction (not repulsion) can be exerted on it; consequently, the diaphragm moves inward for both half-cycles of current, instead of alternately inward and outward as described in (1) above. The sound wave produced by this action would have two condensations and two rarefactions for each cycle of current. The sound, therefore, would have a fundamental frequency twice as great as that of the current, as well as a distorted waveform. Since these results would cause the sound to be considerably different from the original sound introduced at the transmitter, this system, which does not contain a permanent magnet, would be useless for telephone transmission.

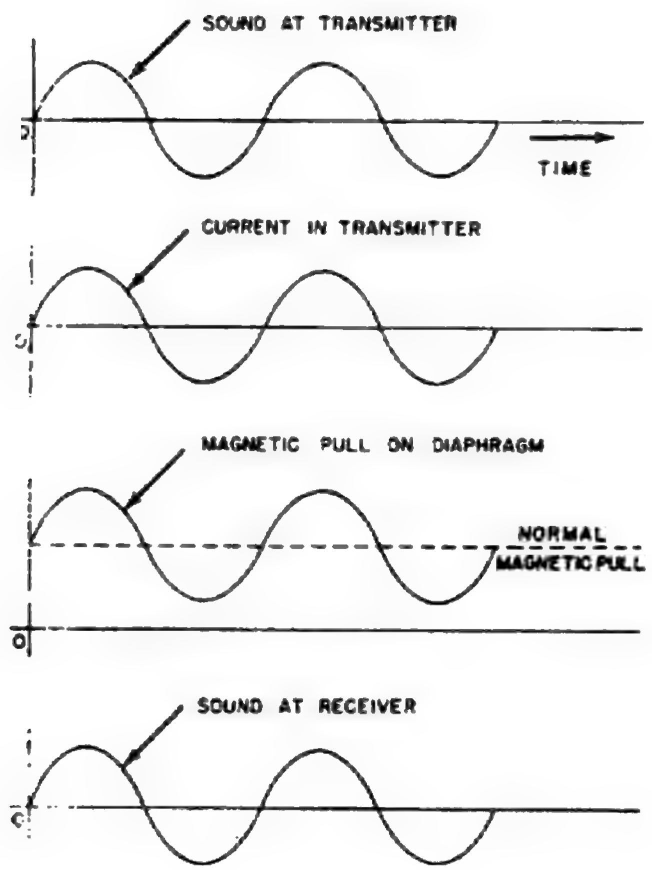


FIGURE 16. Waveforms in Simple Telephone System

b. Application of operating principle to practical magnetic-diaphragm receiver.

(1) In the early telephone receivers devised by Bell, a bar magnet was used to supply the permanent magnetic field (A, fig. 18). Bell actually used two receivers of this type in his early telephone system, one serving as the transmitter and the other as the receiver. Later, the efficiency of the receiver was improved greatly by using a horseshoe magnet in place of the bar magnet, as shown in B. Because the length of the magnetic path is much shorter in the horseshoe magnet, the magnetic field is concentrated in the region between the poles. This increases the pull on the diaphragm for a given value of current, and therefore produces sound waves of greater intensity. The modern receiver unit incorporates a modification of the horseshoe magnet. This, with the use of better magnetic alloys, has improved the design and performance of the receiver.

(2) In a later chapter it will be shown that the receiver winding occasionally must have direct current flowing through it. Because of this requirement, the receiver is connected in such a manner that the field produced by the direct current in the coil aids the field of the permanent magnet. This increases the strength of the field, and results in a stronger pull on the

diaphragm. The process by which direct current in winding produces an aiding field is called poling, because the polarity of the direct current must be correct.

(3) Permanent magnets operate uniformly if they are not subjected to shocks or other abuse. Sudden and violent jarring partially destroys their magnetism, and makes them less effective in telephone receivers. A weak magnet exerts a weaker normal pull on the diaphragm, causing unequal displacement on each side. This results in distorted vibration and distorted sound.

24. Structure of Modern Receiver.

a. C, figure 18, shows the front view and a cross-sectional side view of a modern receiver unit, designed to be mounted in several types of telephone instruments. The receiver winding is wound around two permalloy pole pieces, each of which is welded to a cobalt-steel bar magnet. These magnets are made of a recently developed magnetic alloy which has high permeability, giving a strong magnetic field. The magnets and pole pieces are fastened to a zinc-alloy frame. The diaphragm is made of a special steel alloy. It is not clamped, but rests on a ring-shaped ridge; the pull of the magnets holds it in place. It is protected in front by a silk screen, and its vibration is controlled by a silk acoustic resistance disk attached at the rear. The entire unit is held together by a brass clamping ring. Two silver-plated contacts, for electrical connections, are mounted on the back.

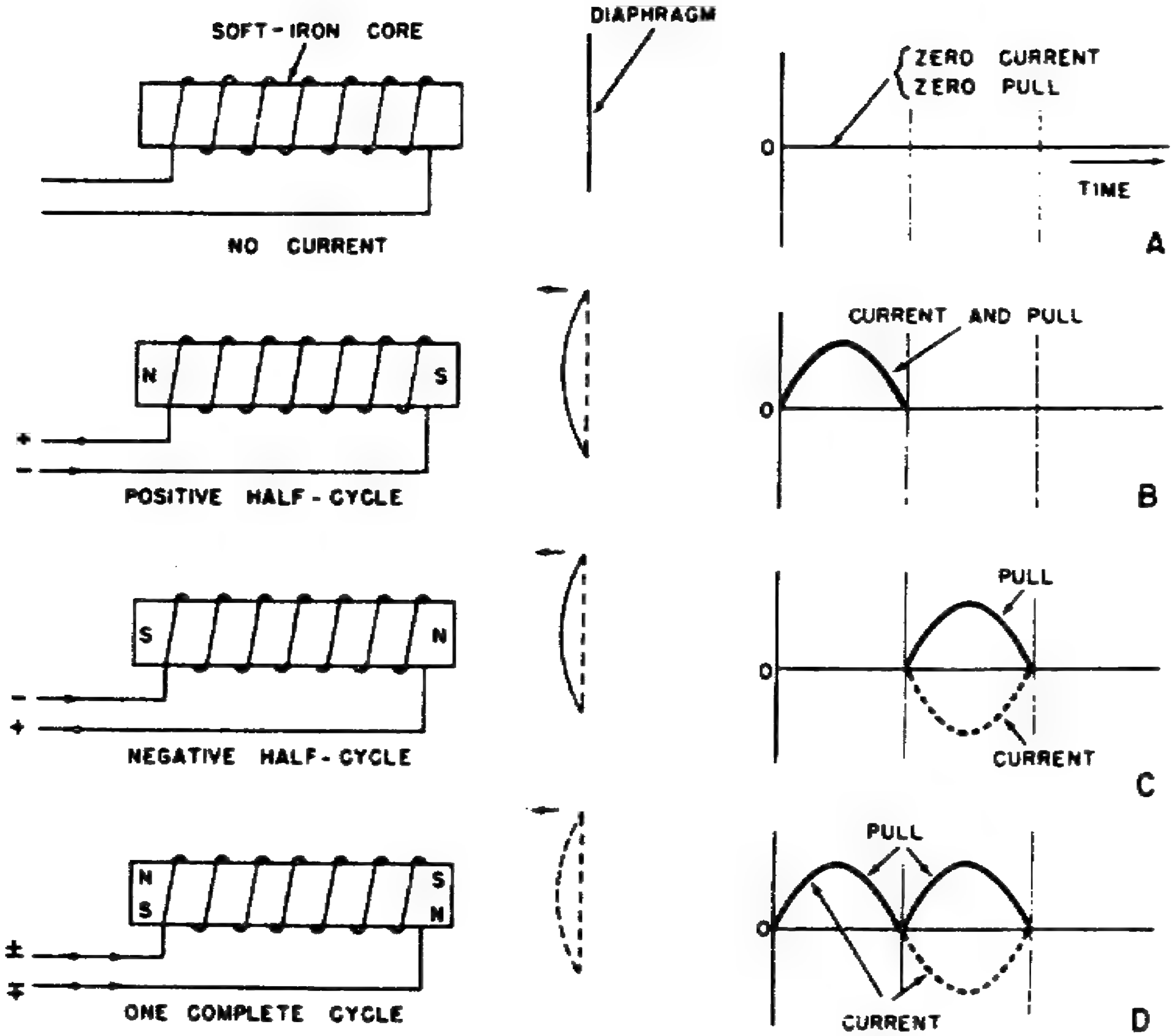


FIGURE 17. Action of Soft Iron-ore Electron Agent on Diaphragm

b. A receiver that provides improvements in efficiency and frequency response is shown in figure 19.

(1) The simple diaphragm of earlier receivers is replaced by a ring armature, a dome-shaped diaphragm of phenolic impregnated fabric cemented to a circular magnetic ring. The outer edge of the ring rests on a circular seat of nonmagnetic material. The inner edge is close to a circular pole piece which conducts the flux from a ring-shaped permanent magnet. This design lowers the mechanical impedance of the diaphragm and improves the radiation efficiency. As a result, when the receiver is held off the ear, the intelligibility of speech is much better than that of other receivers.

(2) An acoustical network couples the back chamber of the diaphragm through four holes covered with acoustic resistance fabric to the handset cavity. The chamber above the diaphragm exhausts through the holes in the receiver cap. The receiver response is virtually flat from 400 to 3,500 cps (cycles per second)--an improvement over earlier receivers.

(3) A varistor, or nonlinear resistance, protects the user from high acoustic levels caused by transient electrical disturbances in the telephone circuit. This varistor also protects the receiver magnet from demagnetization hazards of such disturbances.

c. The receiver and transmitter units are mounted for convenience in an instrument called a handset. Figure 20a is a disassembled view of a handset, showing the transmitter element, transmitter cap, receiver element, and receiver cap. When the receiver cap (earpiece) is screwed on tightly, it exerts a pressure on the receiver element, forcing the two contacts against two contact springs. These contact springs are connected to the external wiring of the receiver. Like the transmitter, the receiver element may be removed for servicing or replacement by unscrewing the cap. In the typical modern combined hand-telephone set shown in figure 20b, the handset rests on a cradle base when not in use.

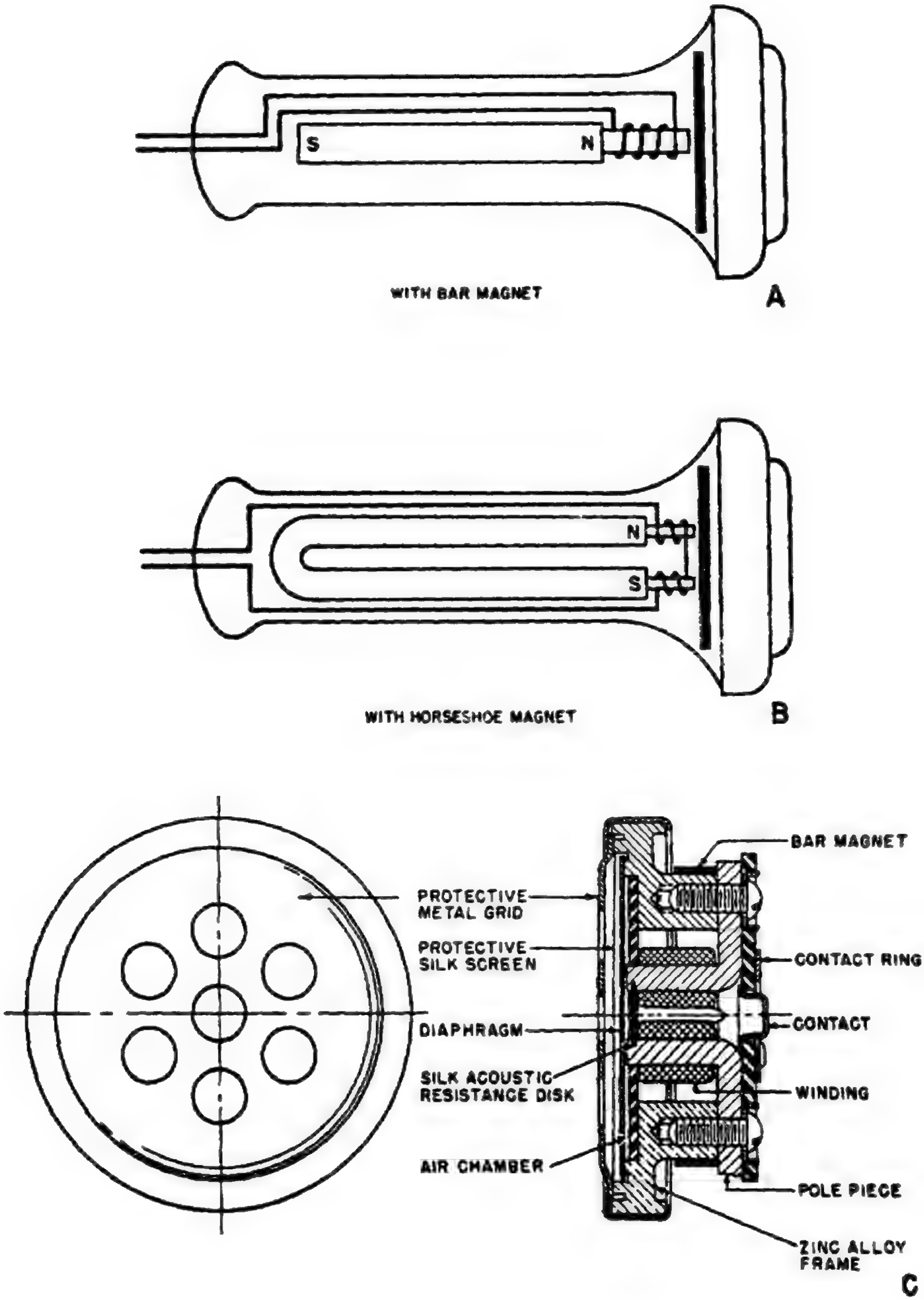


FIGURE 18. Telephone Receivers

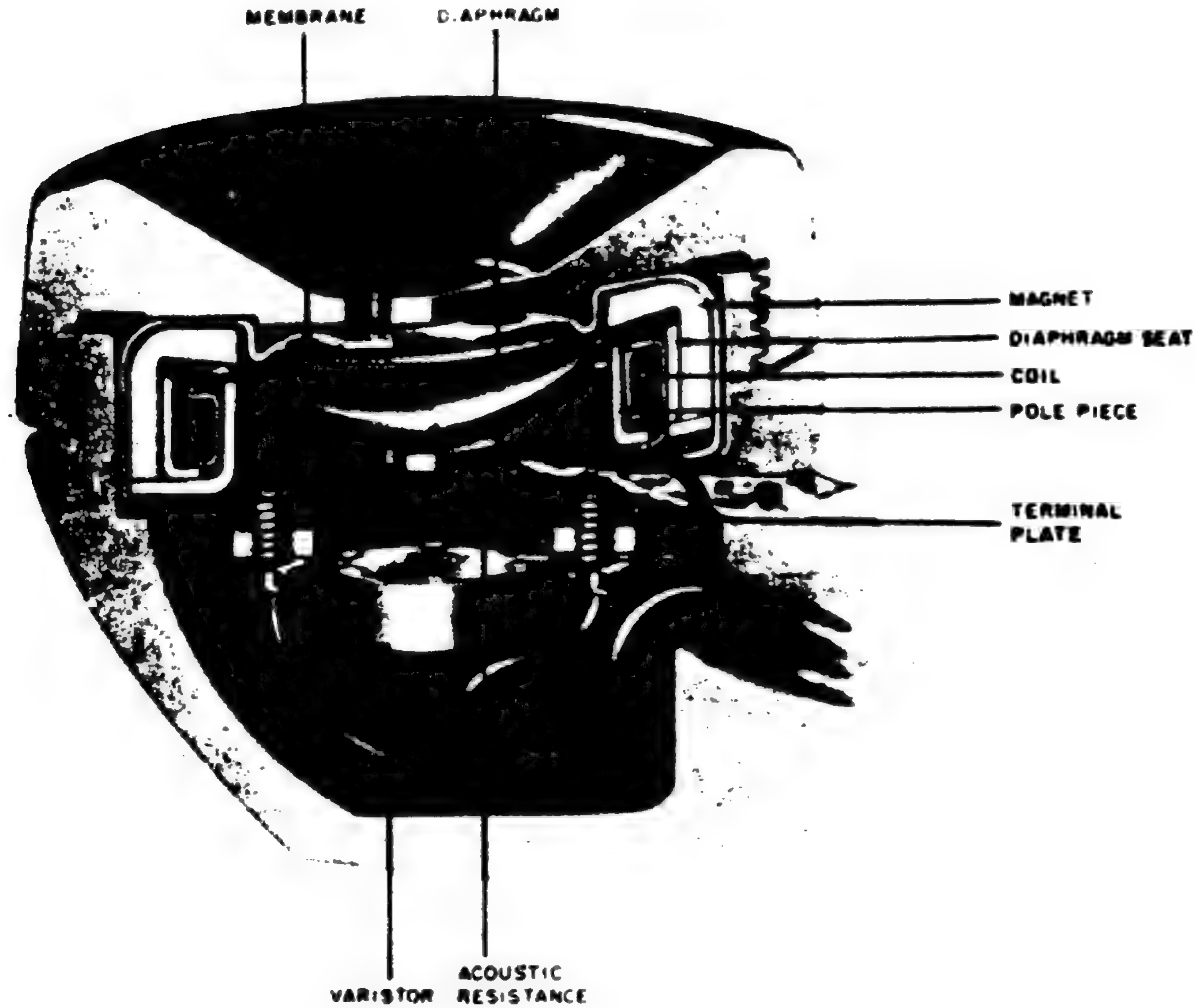


FIGURE 19. Modern Receiver Unit with Ring Armature

25. Circuit Diagrams.

a. Identification of components of circuit diagrams. The study of telephony involves an understanding of the operation and assembly of equipment consisting of many component parts. Some of the parts are small, some rather large. The process of learning is simplified greatly if these parts can be identified readily. Identification means more than recognizing them, however. It includes the ability to visualize how and where each part is connected in a circuit, and knowledge of the theory and function of the part in that circuit. It includes a thorough understanding of the relation of each part in a circuit to other parts, for only with this understanding can the skill necessary for

tracing circuits be acquired. In later chapters of this manual which deal with actual telephone circuits, the theory and function of each part will be explained as soon as the part is introduced, and the relation of each part to the others in the circuit will be presented by means of text and diagrams.

b. Types of circuit diagrams (fig. 21). Three basic types of circuit diagrams--pictorial, wiring, and schematic--will be used extensively in this manual, and now will be described. In addition, frequent use will be made of block diagrams.

(1) An example of a pictorial diagram is shown in A. This is a picture drawing of the actual physical layout or assembly of the component parts of a circuit, showing the parts either as they appear to the eye, or in a form which emphasizes some feature of their operation. The parts may be photographs of equipment, if they are arranged to show the relationships among them. Pictorial diagrams are useful particulary to people untrained in the theory of operation of the circuits they illustrate.

(2) B is an example of a wiring diagram. This type is used primarily to show a wireman or serviceman the proper hookup for a piece of equipment. The emphasis in wiring diagrams is on the connection of cables and other wires to appropriate terminals, not on the operation of the circuit.

(3) The schematic diagram, shown in C, is not a lifelike drawing of the component parts of a circuit, or a means for indicating their connection. Instead, standard, conventional symbols are used, and the position of the symbols in the diagram does not necessarily correspond to the location of the parts in the actual equipment. Schematic diagrams usually are more compact and easier to trace than pictorial diagrams, and they are used more often. They make it possible to present a more logical explanation of the voltage and current relationships in electrical circuits than is possible with other types, and they allow the emphasizing of important features of the circuits. Schematic diagrams will be used extensively in explaining the operation of the telephone circuits discussed in this manual.

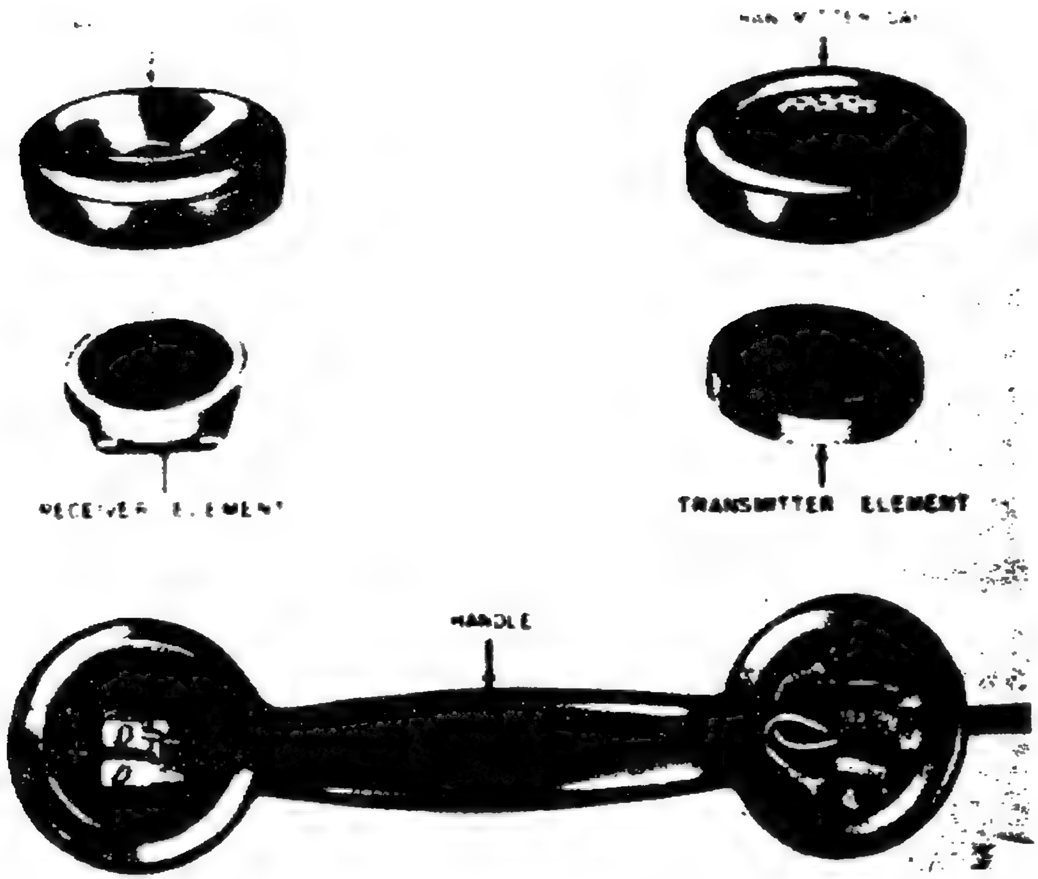


FIGURE 20a. Handset, Disassembled

FIGURE 20b. Modern Combined Hand-telephone Set

26. Reading of Schematic Diagrams.

The ability to trace and understand the schematic diagrams of telephone circuits can be obtained rapidly if the problem is approached in an intelligent manner. Do not attempt to memorize complicated diagrams. The principles and procedures followed by telephone men, described below, should be followed to acquire skill in reading and understanding schematic diagrams.

a. Learn the electrical principles underlying the operation of the particular circuit. This includes a knowledge of the kinds of current flowing in the various parts of the circuit, the voltage across the various parts, and the power dissipated in the circuit.

b. Memorize the symbols for the component parts of telephone circuits. These symbols will be introduced at the time the operating principle of each part is explained. Learn to identify the symbol with the actual appearance of the part.

c. Break down a complex circuit into a number of simpler circuits. Frequently, certain small groups of parts form relatively simple units within a complex circuit. For example, a diagram of a complete telephone system can be broken down into a transmitter circuit, a receiver circuit, a ringing circuit, relay circuits, and several other smaller circuits. Learn to recognize these small groups as units, and to relate these units to the others. In the following pages, complete circuit diagrams will be built up step by step; and frequently, as each new smaller unit is introduced, its position in the circuit will be emphasized by the use of heavier lines than those in the rest of the circuit. Take advantage of this, not only to learn the function of the unit itself, but to understand its relation to the rest of the circuit.

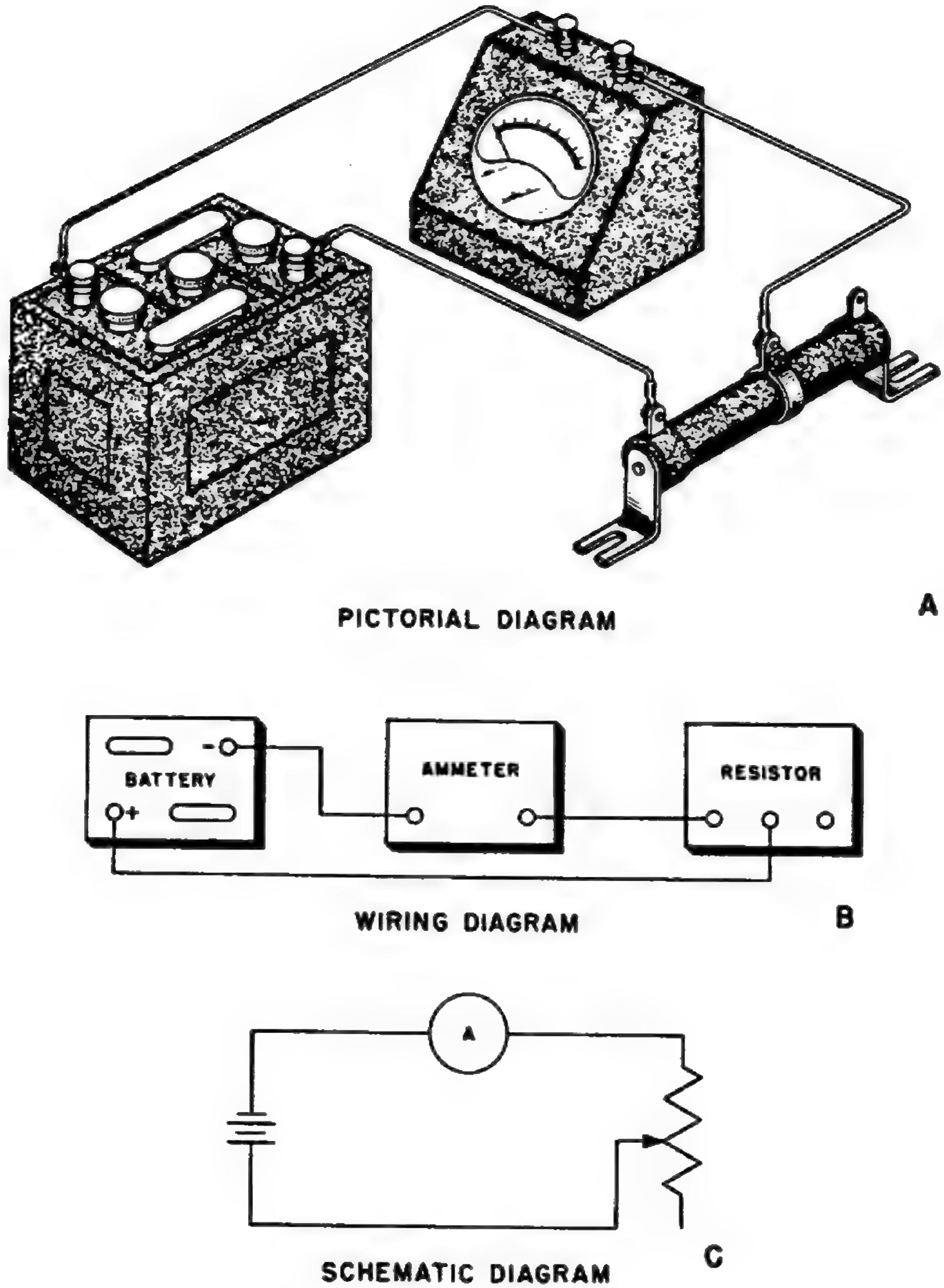


FIGURE 21. Types of Circuit Diagrams

d. Learn to think of each part or unit in a circuit in terms of its function in the circuit. An understanding of why a particular part is included is extremely helpful in learning its position in a schematic diagram.

e. Form the habit of visualizing the position of a unit in the actual equipment from its position in a schematic diagram of the equipment. This will prove helpful when it is necessary to work on the equipment from a schematic diagram. Remember that the position of the symbol in a schematic diagram does not correspond necessarily to the location of the unit in the equipment.

f. Learn to distinguish between the electrical circuit and the mechanical operations associated with the circuit.

g. Review, from time to time, the symbols learned previously, and the relationships among the smaller units which make up the complete circuit.

h. Follow faithfully all of the foregoing principles and procedures, for they are indispensable to the rapid acquiring of skill in the reading of schematic diagrams.

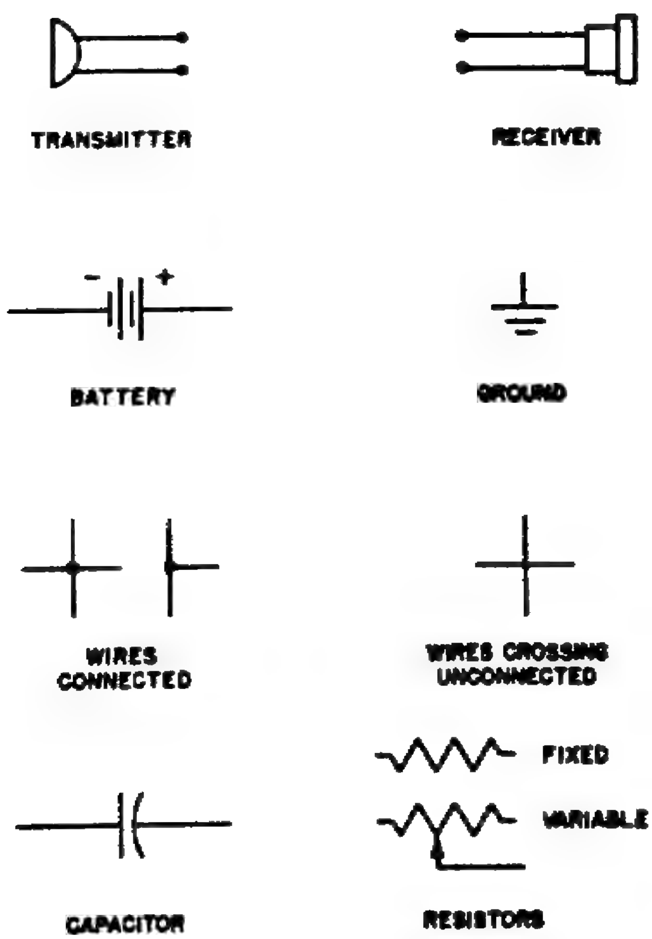


FIGURE 22. Telephone Symbols

27. <u>Telephone Symbols</u>.

This chapter has included discussions of the operating principles of telephone transmitters and receivers. These units, together with such electrical devices as batteries and resistors, are basic components of telephone systems. Figure 22 shows most of the symbols for the units and devices so far discussed. A more complete list of the fundamental electrical symbols used in telephone circuits is contained in the appendix.

28. Summary.

a. The telephone as invented by Bell in 1875 was crude and limited in efficiency. Extending its area of usefulness presented many problems. Within only a few years, many of its basic problems were solved.

b. Present-day telephone systems are very different from early ones, but they have the same basic principles of operation.

c. Sound waves, striking the diaphragm of a carbon transmitter, cause the diaphragm to vibrate with variations of frequency and amplitude corresponding to those of the waves. This causes a corresponding variation in the resistance of a chamber of carbon granules, which in turn causes a corresponding variation in the magnitude of a direct current produced by a battery. This pulsating direct current flows through the primary winding of an induction coil, and induces an alternating emf in the secondary winding. An alternating current flows through a load connected to the secondary.

d. Modern transmitters are designed, electrically and mechanically, for maximum efficiency and minimum distortion and interference from external noise.

e. The carbon transmitter is most common of several types of transmitters in current use.

f. The electrical waves produced by the transmitter are sent over the transmission line and reconverted to sound waves in the receiver.

g. The magnetic-diaphragm receiver contains a permanent magnet which exerts a constant attraction on a diaphragm of magnetic material placed close to it. Around the magnet is a coil. The intensity of the magnet field of the magnet in the receiver varies with the alternating current it receives from the transmission line running to the transmitter, and this causes an alternate increase and decrease in the pull exerted upon the diaphragm. The vibration thus set up produces sound waves which correspond in frequency and amplitude to both the electrical waves in the line and the originating sound waves at the transmitter.

h. Modern telephone receivers efficiently reduce interference from surrounding noise.

i. Skill in reading and understanding circuit diagrams, particularly schematic diagrams, is important in the study of telephony. Acquisition of skill is relatively easy if the proper procedure is followed.

LESSON 1 EXERCISES

In each of the following exercises, select the ONE answer that BEST completes the statement or answers the question. Indicate your solution by circling the letter opposite the correct answers in the subcourse booklet.

1. Assume that you are receiving a long distance telephone call on the hand telephone set shown in figure 20. The telephone system processes the sounds of the voice waves conquer distance by:

a. concentrating the amplified sound waves and transmitting them over wires.

b. transmitting the actual voice of speaker to a receiver.

c. transforming the speaker's voice power into electrical power for transmission to a receiver.

d. concentrating the power of sound waves and transmitting this power to a distant receiver.

2. Such terms as frequency, velocity, amplitude, pitch, quality, and wavelength are used to describe sound waves. In figure 1-1 the characteristic indicated as X is the:

a. velocity.

b. amplitude.

c. frequency.

d. wavelength.

Figure 1-1. The sine wave.

3. As a telephone operator you are conducting a study of the velocity of sound waves and their variations through different transmission media. The medium through which sound travels at the fastest rate is:

a. air.

b. water.

c. solids.

d. a vacuum.

4. If you are talking over the telephone system (refer to chapter 1, paragraph 6b and the formula), and the sound wave of your voice is traveling at a velocity of 1,130 feet per second toward the transmitter, what will be the wavelength of the frequency 500 hertz?

a. 2.26 feet.

b. .442 feet.

c. 22.6 feet.

d. 44.2 feet.

5. The waveforms in figure 5 show the pattern of waves which were produced by different sounds. The component of sound waves that enables us to distinguish between different speakers who pronounce the same word is the:

a. pitch.

b. velocity.

c. amplitude.

d. harmonics.

6. Assume that during an analytic study you discovered that sound waves cover a wide range of frequencies, and that the average human ear cannot respond to all. To what frequency range does the average human ear normally respond?

a. 10 to 300 hertz.

b. 20 to 20,000 hertz.

c. 10 to 3,000 kilohertz.

d. 20 to 200 kilohertz.

7. As stated in paragraph 8a of chapter 1, the fundamental frequency of middle "C" is 256 cps. What then is the frequency of the fourth harmonic of middle C?

a. 640 hertz.

b. 1,024 hertz.

c. 640 kilohertz.

d. 1,024 kilohertz.

8. As a telephone operator you are unable to project your voice at the normal conversational level because of static and transmission line interference. The average power furnished by the lungs to project your voice as loudly as possible is approximately:

a. 0.1 microwatt.

b. 10 microwatts.

c. 1,000 microwatts.

d. 2,000 microwatts.

9. The fundamental frequency range scale shown in figure 6 is the type of reference scale used by the telephone engineers when designing and constructing telephone lines and equipment. The most important factors affecting the design and construction of the telephone equipment is the:

a. power concentration of the normal singing voice and the operator's ability to distinguish between the complete fundamental frequency range and the harmonic frequency range.

b. frequency range of the voice and the equipment's ability to respond to the difference in power delivered by the voice.

c. frequency range of the overtones and the equipment's ability to respond to the difference in power delivered by the fundamental frequency.

d. power concentration of the overtone singing voice and the operator's ability to distinguish between the over tone frequency range and the harmonic frequency range.

10. The thresholds of audibility and feeling vary according to the frequency of the sound. The range of frequencies to which the average ear is most sensitive is:

a. 50 - 500 hertz.

b. 150 - 2,000 hertz.

c. 1,000-4,100 hertz.

d. 8,000-16,000 hertz.

11. In addition to the low input power, the most serious limiting factor to the transmission range of sound-powered transmitters is the:

a. lack of amplifying facilities.

b. poor quality of the transmission media.

c. poor quality of permanent magnets.

d. lack of inflexibility of the diaphragms.

12. The condition of a carbon telephone transmitter can sometimes be determined by measuring its resistance. The normal value of the resistance should measure approximately:

a. 20 ohms.

b. 35 ohms.

c. 100 ohms.

d. 300 ohms.

13. The use of the carbon transmitter in place of the original transmitting device used by Bell has greatly increased the transmitting distance of telephone communication. The current through the carbon transmitter during conversation can be described as:

a. an alternating current.

b. a steady direct current.

c. a pulsating direct current.

d. a complex alternating current.

14. Telephone transmitters generally pick up and transmit undesirable background noises. One transmitter that is most effective in canceling these noises is the:

a. positional transmitter.

b. differential transmitter.

c. nonpositional transmitter.

d. nondirectional transmitter.

15. Several types of telephone receivers are used to convert the electrical waves back to sound wave. The type of receiver most commonly used for this purpose is the:

a. dynamic type.

b. moving-coil type.

c. moving-conductor type.

d. magnetic-diaphragm type.

SITUATION

Assume that the telephone receivers used in your central office telephone system are identical with the receiver shown in figure 19.

Exercises 16 and 17 are based on the above situation.

16. Upon analyzing the construction of the receiver, you determine that the purpose of the circular magnet ring is to:

a. permit the use of smaller electromagnets so that the physical size of the receiver can be reduced.

b. lower the mechanical impedance of the diaphragm and improve the radiation efficiency.

c. prevent the diaphragm seat from vibrating at the same frequency as the membrane.

d. permit the use of larger coils for more current handling capabilities.

17. During your analysis of the telephone construction, you discover that a varistor (fig. 19) is connected to the receiving circuit. The purpose of the varistor is to:

a. eliminate the need of acoustic resistance.

b. protect the user from acoustics levels.

c. prolong the life of the membrane.

d. eliminate sidetone in the receiver.

SITUATION

Assume that you have been assigned to locate a major malfunction that has developed in a central office telephone system.

Exercises 18 through 20 are based on the above situation.

18. Different types of diagrams are used to help the technician locate and repair malfunctions. The type of diagram is best suited for checking proper equipment hookup is the:

a. block diagram.

b. wiring diagram.

c. pictorial diagram.

d. schematic diagram.

19. As the telephone operator you ask the technician how you can learn to read and understand a schematic diagram. One recommended procedure is for you to:

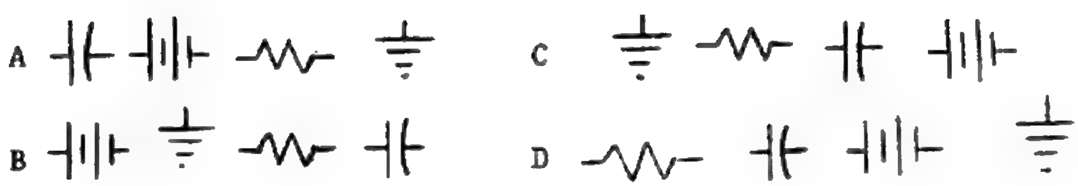
a. memorize the schematic symbols.

b. learn to read the resistance and voltage measurements.

c. learn the physical position of each circuit component.

d. memorize the circuit diagram and all voltage points.

20. Shown in the illustration below are the symbols for a battery, a ground, a resistor, and a capacitor. Which of the following illustrations shows the symbols in the stated order.



CHECK YOUR ANSWERS AGAINST LESSON 1 SOLUTION SHEET (PAGE 192) AND MAKE NECESSARY CORRECTIONS.

LESSON 2

TELEPHONE SYSTEMS

OBJECTIVE:

Action:	You will identify the components of a telephone system by their electronic symbol and describe the operation of (1) a local-battery system, (2) a common-battery system, and (3) analyze switchboard operation.
Conditions:	You will be provided the lesson material and a lesson exercise sheet.
Standard:	You must respond correctly to at least 17 of the 20 questions in the lesson exercise.

CREDIT HOURS:	2
TEXT ASSIGNMENT:	Read inclosed text
MATERIALS REQUIRED:	Pencil or pen
SUGGESTIONS:	None

CHAPTER 3

INTRODUCTION TO TELEPHONE SYSTEMS

29. Components of Telephone Systems.

To provide satisfactory service, the telephone system must include, besides transmitters and receivers, components such as ringers, switchboards, and transmission lines. This chapter explains the overall functions of these additional components and shows how they are used in a number of common telephone systems. Later chapters will present in detail the principles of their operation.

30. Simple Telephone Circuit.

a. The simplest telephone circuit is obtained by connecting a transmitter to a receiver, as in figure 23. In such a circuit, the transmitter may be located a considerable distance from the receiver, perhaps several miles away, and yet a person speaking into the transmitter at station A can be heard by another person at the receiver at station B. One-way telephone communication is effected.

b. One-way communication serves for the transmission of intelligence in one direction, but it is inadequate for most of the purposes for which the telephone is used. Two-way conversation is indispensable. Figure 24 shows how simply this can be arranged. A receiver is added at the transmitting end and a transmitter at the receiving end. With two transmitters and two receivers, so connected, the voice of a person speaking into either transmitter can be heard in both receivers, and two-way communication is effected between stations A and B.

c. Although the circuit in figure 24 can be used as the basis for a simple telephone system, its usefulness is limited. How can a person at station A signal someone at station B to come to the phone so that conversation may begin? Although the circuit shown in figure 24 does not provide a means for alerting a receiver of an incoming call, is arranged simply as shown in figure 25. At each station, A and B, signaling (ringing) circuits are added, and these make it possible for a person at either station to signal the other station when conversation is desired. A signaling circuit includes a ringer (bell or buzzer) and a hand generator. A person at station A, wishing to talk with someone at station B, turns the crank of the hand generator. This generates an ac voltage which send a signal current over the transmission line to operate the

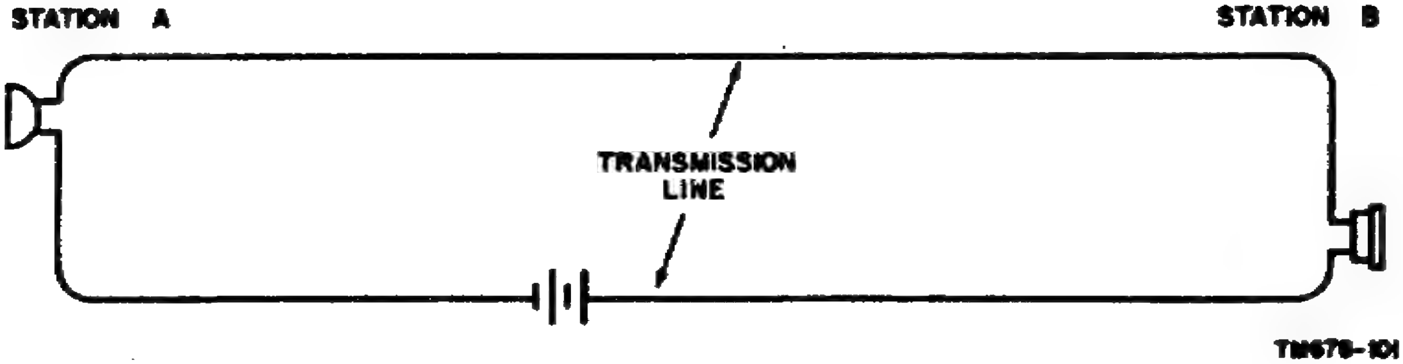


FIGURE 23. Simple telephone circuit.

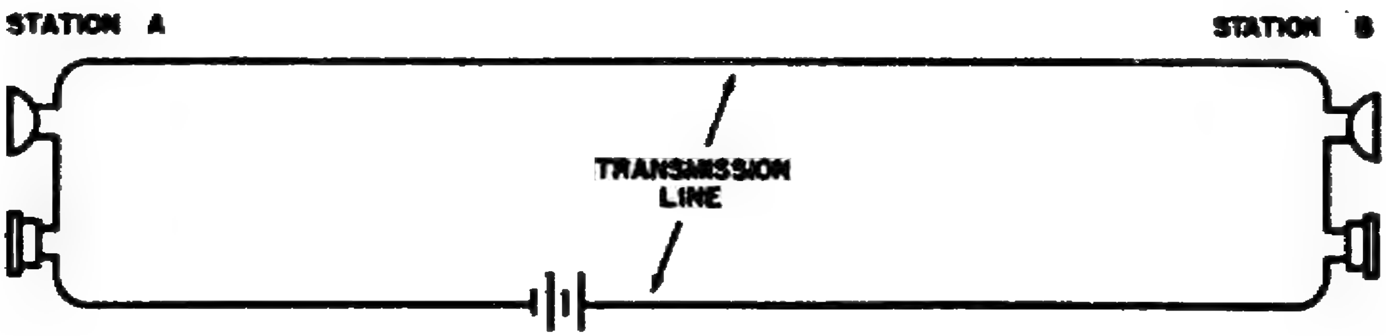


FIGURE 24. Practical Telephone Circuit

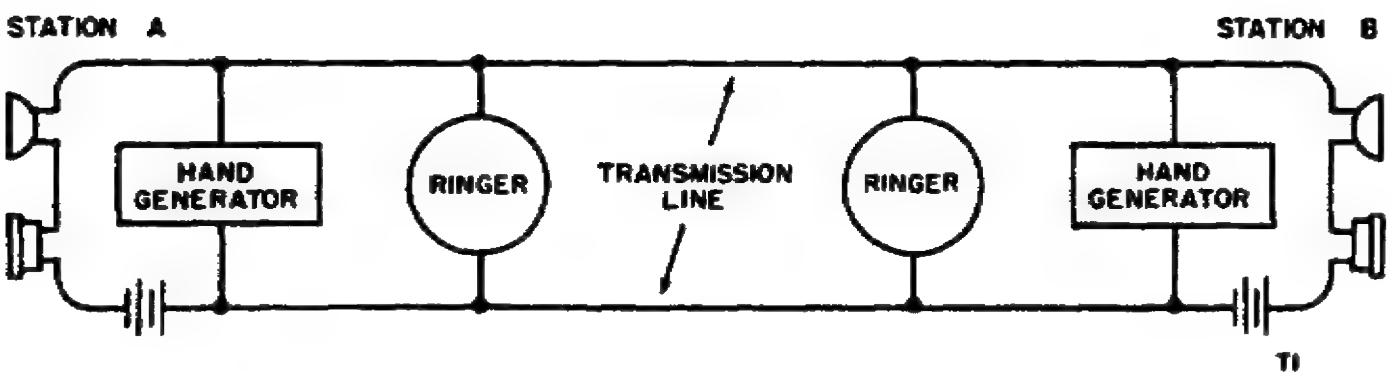


FIGURE 25. Circuit with Hand Generator and Ringers.

ringer at station B. The sounding of the ringer attracts the attention of someone, who thereupon answers the call. The transmission line connecting the two stations conducts connecting the two stations conducts both the voice currents and the signaling current; also, although a ringer has been mentioned as the signaling device and a hand generator as the source of signaling current, other devices may be used for the generation of signaling current and the signaling itself. These will be considered later in detail.

31. Telephone Switchboard.

a. A telephone system frequently consists of hundreds, even thousands, of telephone stations. In operation, the system permits voice communication between any of the telephone stations which are part of it. The simple circuit of figure 25 can be used in a telephone system if each station is connected by a similar circuit to all the other stations in the system. Such an arrangement would require the use of two wires and a switch from each station to every one of the other stations. It would be impractical for serving a large number of telephone stations; for even a few, the system would be a maze of wires. The block diagram of figure 26A shows the wiring required to interconnect eight stations.

b. An important saving in line wire is obtained by including in the system a centrally located switchboard. Each telephone station then is connected directly to the switchboard, not to each of the others. The connecting wires and their attachments constitute a transmission line. Conversation between any two stations is made possible by interconnecting their transmission lines at the switchboard. The connections are made by a switchboard operator or attendant by means either of switches or, more frequently, cords with plugs for insertion in jacks connected to the ends of the lines from the two telephones. The block diagram of figure 26A shows the eight telephone stations of figure 26B connected to a switchboard.

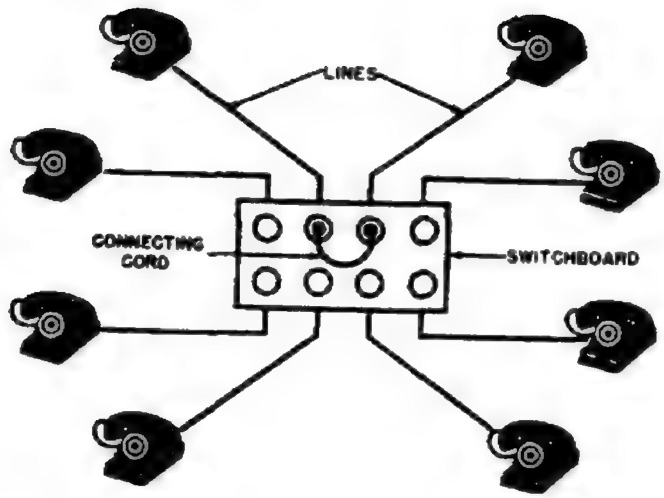


FIGURE 26A. Telephone Stations Connected to Switchboard.

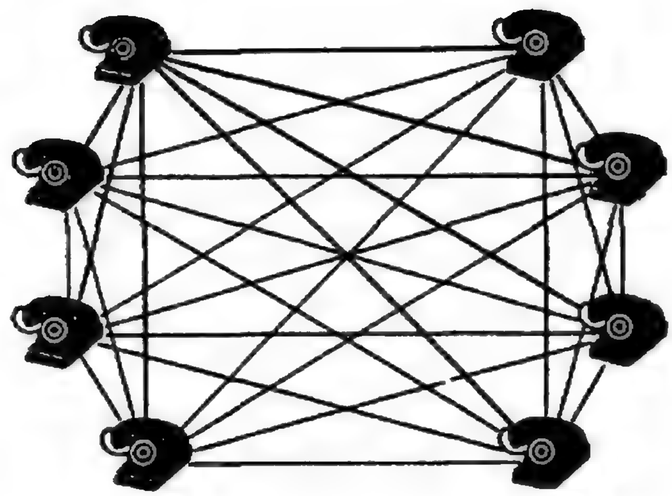


FIGURE 26B. Station Interconnection of Telephone System Without Switchboard.

c. With the circuit arrangement of figure 26A, all conversations take place through the switchboard. A person at station A wishing to call a person at station B first signals the switchboard operator. When the operator replies, the caller supplies the name or number of the station being called--station B, in this case--and the operator then completes the connection at the switchboard and signals station B. When station B answers, conversation between the two telephone stations proceeds.

32. Telephone Central Office.

A switchboard or other switching device, together with associated equipment, is located at a telephone central office. More accurately, they comprise the telephone central office. The equipment may include a switchboard of one or more positions so interconnected that telephone service can be given to a greater number of telephone stations in an area. Switchboard is the name given to that component of a telephone system where connections are made among the associated lines or stations by an operator. The service requirements determine the capacity of the switchboard, and the traffic (number of connections) requirements determines the number of operators attending at the switchboard. As switchboards increase in size, beyond the ability of one operator to handle the traffic, and a second operator is engaged at the switchboard, the switchboard is designed especially to accommodate the second operator, and to distribute the line jacks in such a way that the traffic load is distributed

evenly between the operators. Since each operator will occupy a position at the switchboard, and since two positions are required to accommodate two operators, a switchboard so designed is referred to as a two-position switchboard. In many instances, switchboards reach to 30 or more positions.

33. Telephone System.

A telephone system with one central office consists of a number of telephone stations connected by lines to the central office, so that any two telephones of the system may be interconnected for two-way conversation. Such a system may serve a few or thousands of stations; it may have more than one central office. A system includes the individual telephone stations, the outside plant equipment for connecting each telephone station to a central office and for interconnecting central offices, and all the central-office equipment required for making connections between the telephones and switchboards. Whatever the size and extent of the system, and however many switchboards, and central offices are a part of it, any telephone station can be connected with any other telephone station. The telephone stations, central office, and connecting lines shown in figure 26B constitute a telephone system with a single central office.

34. Telephone Exchange.

A telephone system which provides telephone communication within a particular local area, such as an Army post, maneuver area, town, village, or city, is a telephone exchange. It may have one or more central offices, depending on the extent of the telephone service and traffic that is handled.

a. The switchboard and eight telephone stations of figure 25A would be called an exchange, although an exchange usually includes hundreds of telephone stations and their associated lines, switching facilities, and accessory equipment.

b. By interconnecting telephone exchanges, service can be provided between telephone stations served by two or more exchanges. The transmission lines interconnecting the central offices of different exchanges are called trunk lines, or trunks. When a person at station A in exchange I (fig. 27) wishes to call a person at station B in exchange II, the procedure is only a little more extended than the procedure within a single exchange. The caller

at station A signals (attracts the attention of) the switchboard operator in exchange I and asks to be connected to station B in exchange II. The operator responds by relaying the number of the called station over the trunk to the switchboard operator in exchange II, who then signals station B and completes the connection. The figure shows the connecting cords and completed connection between station A and station B through the trunk connecting exchange I and exchange II.

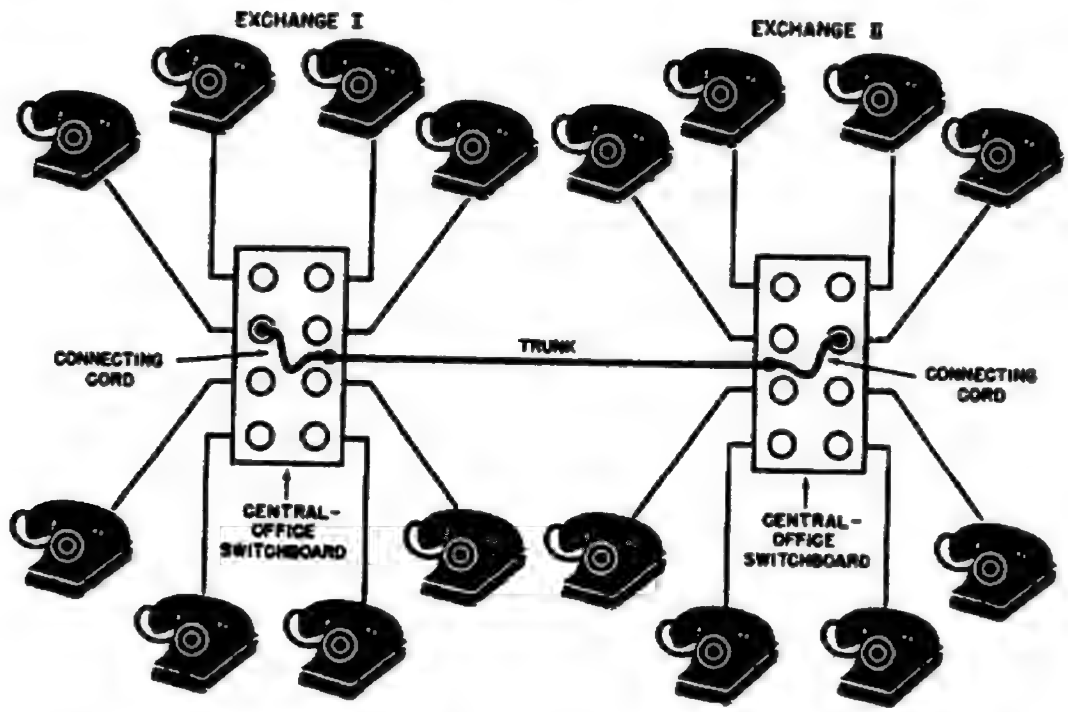


FIGURE 27. Telephone Exchanges Connected by Trunks.

35. Summary.

a. One-way communication can be effected with a transmitter at one telephone station, a receiver at the other, a battery, and connecting lines.

b. Two-way communication requires at each telephone station at least a transmitter, a receiver, and a means for signaling the called station.

c. For economy and efficiency, telephone stations usually are connected to a switchboard or other switching device in a central office, and intercommunication is effected through it.

d. Telephone central offices are interconnected by trunk lines, permitting communication between telephone stations connected to different central offices.

CHAPTER 4

LOCAL-BATTERY TELEPHONY

36. Equipment of Local-Battery Telephone System.

The equipment of the local-battery telephone system may be classified as telephone-station equipment, central-office equipment, and interconnecting equipment. The unit of equipment at the telephone station is the telephone set, and the unit of equipment at the central office is the switchboard. The interconnecting equipment is the telephone line. Because electrical properties of the telephone line are, in general, similar for both the local-battery and the common-battery systems, discussion of the line will be deferred for a later chapter, following the discussion of the common-battery system.

37. Telephone Set.

In both systems, the telephone set, often simply called the telephone, is the device supplied to the telephone user to initiate and receive telephone calls. In the telephone circuit of figure 25, the group of components at each station comprises a simple telephone set. The group includes the transmitter, the receiver, the hand generator, and the ringer.

a. Principle circuits of telephone set. The components of the telephone set of both systems are connected to provide two principal circuits: the talking circuit in A, figure 28, and the signaling circuit, shown in B. Each one is the telephone circuit of figure 25 modified to represent two local-battery telephone sets connected directly to each other. The circuits of the telephone sets are completed by the telephone line connected to terminals L1 and L2 of the sets.

(1) The talking circuit of the telephone set provides an electrical path for the voice current. Its prime components are the transmitter and the receiver. In the local-battery telephone set, it also includes a battery. In the two-station local-battery system shown in A, the heavy lines show the com-

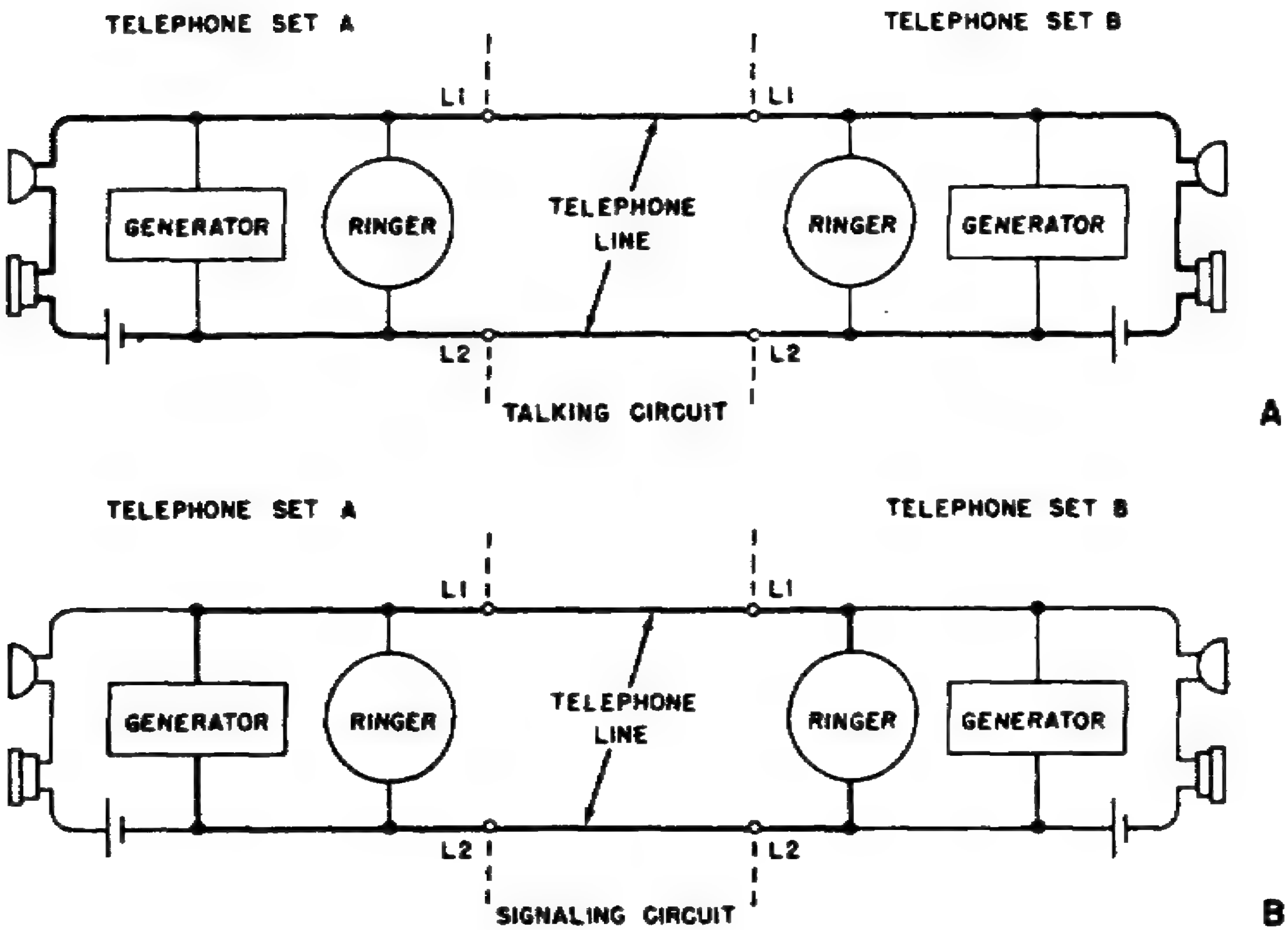


FIGURE 28. Circuits of Local Battery Telephone Sets.

plete talking circuit, which includes the transmitters, the receivers, the batteries of the two telephones, and the connecting telephone line. Thus, voice currents generated by a person speaking into the transmitter of one telephone have a complete electrical path through the telephone line to the receiver of the other telephone.

(2) The signaling circuit of the telephone set provides an electrical path through the signaling device for the signaling current. Its prime component is the ringer. In the local-battery telephone set it also includes a hand generator. In B, the heavy lines show the complete signaling circuit between two telephones. It includes the generator of telephone set A, the ringer of telephone set B, and the connecting telephone line. Rotation of the crank of the

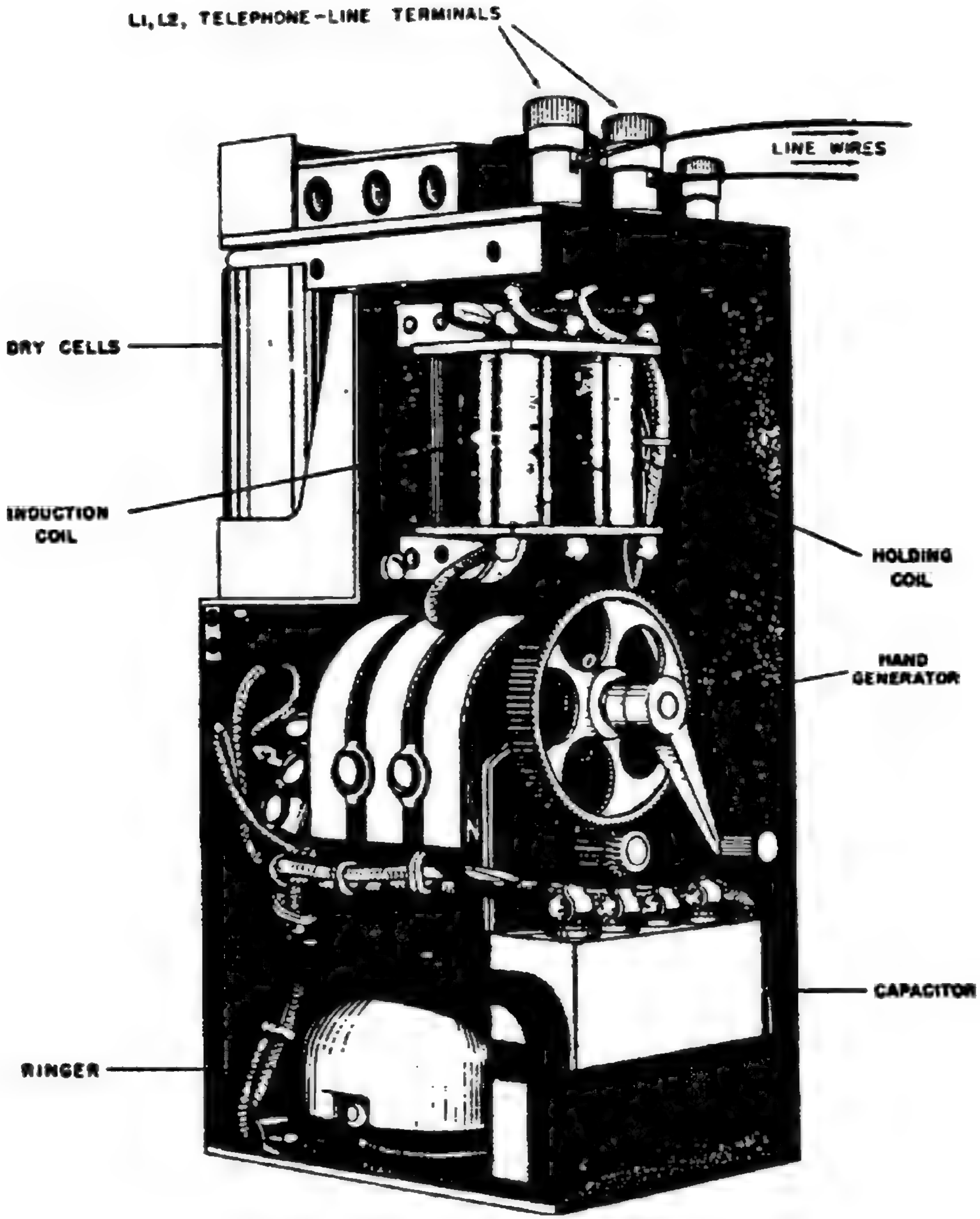


FIGURE 29. Local-Battery Telephone Set, Excluding Handset.

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hand generator of telephone A generates an alternating current which is conducted by the telephone line to the ringer of telephone B and causes it to operate. The switches referred to are not shown in the illustration. A similar circuit exists between the hand generator of telephone B and the ringer of telephone A.

b. Components of telephone set. The components of a local-battery telephone set, excluding the handset, are shown in figure 29. In addition to the hand generator, the battery, and the ringer, there are an induction coil and a capacitor to improve electrical efficiency and performance.

38. Battery.

The function of the battery in the local-battery telephone set is to supply the current for the transmitter. The battery consists of two or three dry cells, which obtain their electrical energy from the chemical action of the materials of which the cell is composed. The chemical action during current flow produces an accumulation of gas bubbles around the positive electrode, which insulates the electrode and increases the internal resistance of the cell. This action of the cell is called polarization. The manganese dioxide contained in the dry cell neutralizes the polarization, but its action is slow, and a continuous drawing of current causes the emf of the cell to fall rapidly. If the cell is given a short rest, however, the depolarization reaction catches up, and the emf increases to nearly its original value. Dry cells therefore are suited particularly for intermittent use. The emf of a new dry cell is about 1.53 volts, and it decreases with age.

39. Handset Switch.

a. Function. A handset switch is usually a normally open, momentary (spring-return) switch. When pushed, it connects the transmitter in the talking circuit. When released, the transmitter is out of the circuit, thus conserving the battery when the transmitter is not in use.

b. Push-to-talk handset switch. A, figure 30, illustrates a handset switch of push-to-talk type, frequently used in local-battery telephone sets. It consists of an assembly, or pile-up, of flat, spring-metal conductors, separated by insulators, as in B. Welded to the ends of the conductors are contacts made of a special alloy which withstands arcing when the switch is opened and closed. The contacts are closed by rotation of the butterfly nut attached to the short shaft which passes through the plate.

When the butterfly nut is released, the spring action of the conductors opens the contacts and restores the switch to its normal, or open, position. The push-to-talk handset switch usually is mounted in the telephone handset between the transmitter and receiver (fig. 30). So located, the telephone user can connect the battery readily when speaking and disconnect it when listening. Figure 31 shows another handset with a push-to-talk switch. When speaking, the switch is pressed downward instead of sideways. On this handset, the receiver unit has been made almost flat to allow the unit to be slipped under a helmet.

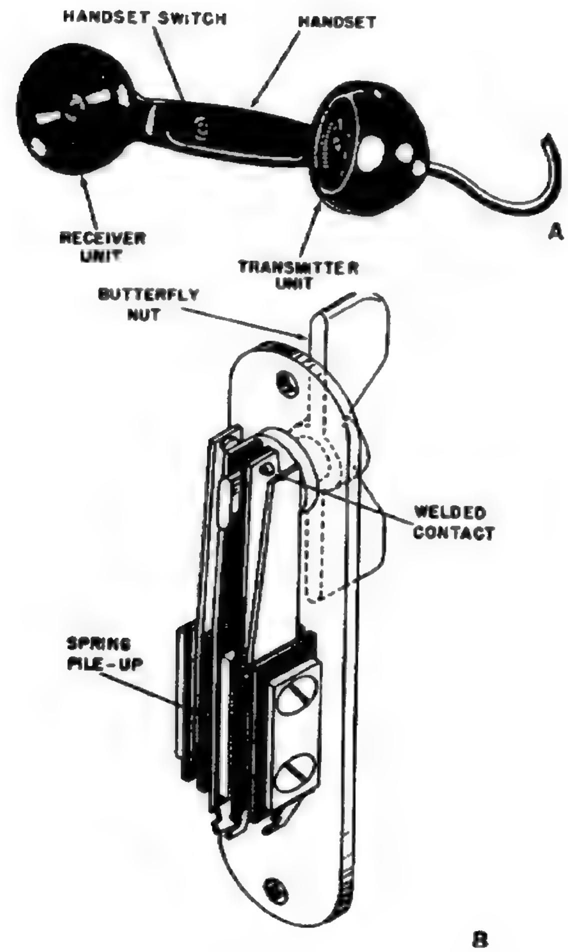


FIGURE 30. Handset with Push-to-Talk Switch

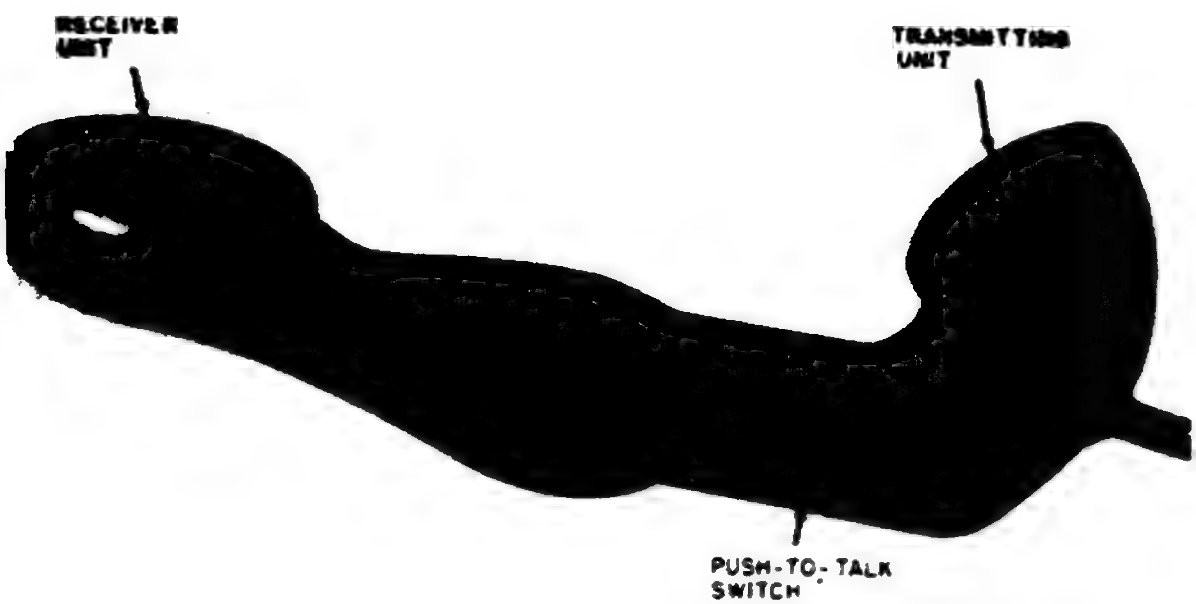


FIGURE 31. Military Handset with Push-to-Talk Switches.

c. Circuit with handset switch.

(1) Figure 33 shows the talking circuit of two local-battery telephone sets, each of which includes a handset switch. It differs from the circuit of figure 28 in that the transmitters and receivers are in parallel instead of in series. This manner of connecting the components automatically results in a closed talking circuit between the two telephones when either handset switch is closed. This would not be the result if the components were connected in series with each of the transmitters; in the normal position, the spring-metal conductors hold the handset switch open, and the talking circuit would not be completed unless both handset switches were closed at the same time. In use, this could be managed, but it would require, between the persons speaking, a coordination that is unnecessary with the circuit of figure 33.

(2) The heavy lines (fig. 33) show the complete talking circuit between the two telephone sets: the transmitter, the battery, and the handset switch of telephone A and the receiver of telephone B. The handset switch of telephone A is shown in the talking (closed) position, and that of telephone B is in the listening (open) position. (Telephone circuit diagrams usually show the switch in the open position.)

40. Handset.

In most telephone sets, the transmitter and receiver units are contained in a single mounting, the handpiece, also called the handle and the handset handle. The combination of handpiece with transmitter, receiver, and connecting cord is called the handset. In the local-battery telephone set, the handset usually includes the push-to-talk handset switch. Figure 32 is an exploded view of the components of a local battery telephone handset.

a. Advantages of handset. The handset provides a convenient support or mounting for the transmitter and receiver. In addition, its design results in an increase in the output of the transmitter. The transmitter is at the proper distance from the mouth of the telephone user when the receiver is against his ear; more of the sound energy of the speakers' voice is directed into the transmitter than might otherwise be the case, and the result is a greater average output of voice current.

b. Structure of handset. The material of the handpiece is molded bakelite or a phenol plastic. Its ends are designed to contain the transmitter and receiver elements. These are retained by molded bakelite or phenolic plastic caps, perforated to pass the sound energy. The transmitter cap is called the mouthpiece, the receiver cap the earpiece. Connections to the transmitter and receiver are made by silver-plated contact springs, fastened to terminals molded in the plastic. In the local-battery telephone handset, the handle is recessed for mounting the push-to-talk switch in the handle. Metal tubes extending through this handle carry the necessary conducting wires between the transmitter, receiver, and handset switch.

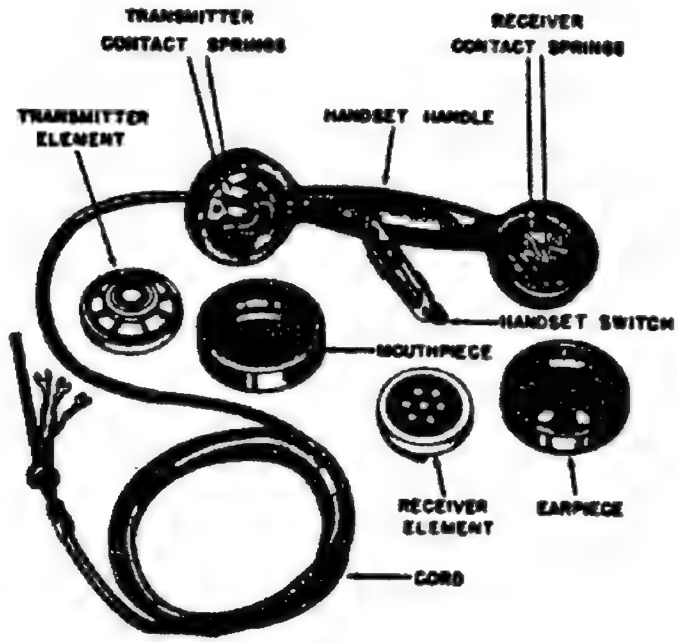


FIGURE 32. Exploded View of Handset of Local-Battery.

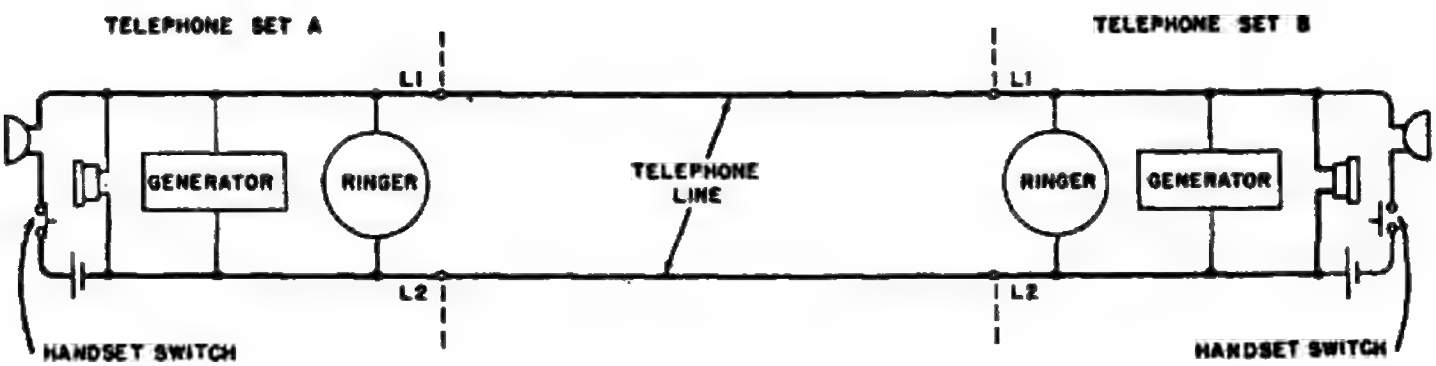


FIGURE 33. Talking Circuit of Two Telephone Sets with Handset

c. Circuit of handset. The broken lines of figure 34 show the wiring of the local-battery telephone handset. The receiver terminals and the handset switch are connected to terminals in the transmitter end of the handle. A three-conductor cord connects the handset to the telephone set. In practice, the individual conductors of the cord usually are identified by the color of the conductor leads; here (and in most circuit diagrams) they are designated T for transmitter, C for common, and R for receiver.

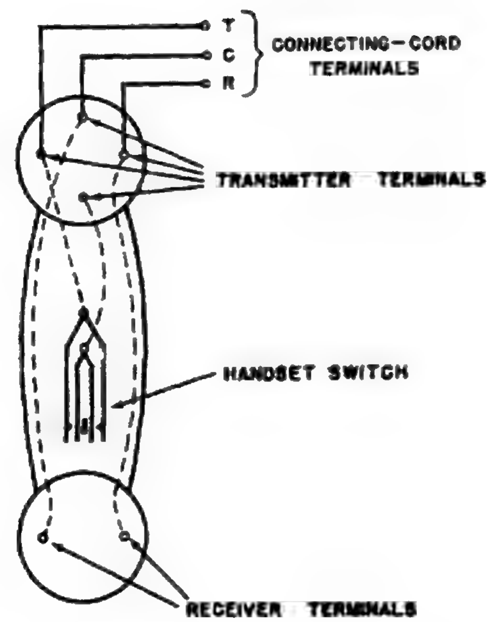


FIGURE 34. Wiring Diagram of Handset with Hand Switch.

41. Induction Coil.

The circuits of the telephone sets of figure 28, using dry cells alone, can be used to provide voice conversation only between telephone sets separated by short distances. The range may be extended, however, and performance and efficiency may be improved, by including an induction coil in the circuit.

a. Functions. The induction coil performs two functions in this particular telephone set. First, it increases the voltage of the voice current generated by the transmitter. Second, it separates the transmitter and receiver currents so that the direct current of the transmitter circuit does not pass through the receiver (secondary) circuit.

b. Circuit. The circuit of a local-battery telephone set with an induction coil is shown in A and B, figure 35. The induction coil consists of two separate coils which have a common connection and are wound on an iron core. One coil, the primary winding, receives the electrical energy; the

other, the secondary winding delivers the electrical energy to the circuit. The induction coil separates the circuit of the telephone set two circuits, the transmitting circuit and the receiving circuit.

(1) The transmitting circuit is emphasized by the heavy lines in A. This circuit includes the primary winding of the induction coil, the transmitter, the handset switch, and the battery, all in series. When the handset switch is closed, direct current from the battery is supplied only to the primary circuit.

(2) The receiving circuit is shown by the heavy lines in B. This circuit includes the secondary winding of the induction coil and the telephone receiver.

(3) The function of the transmitting and receiving circuits of the telephone set will be considered after the following discussion of the basic principles of the induction coil.

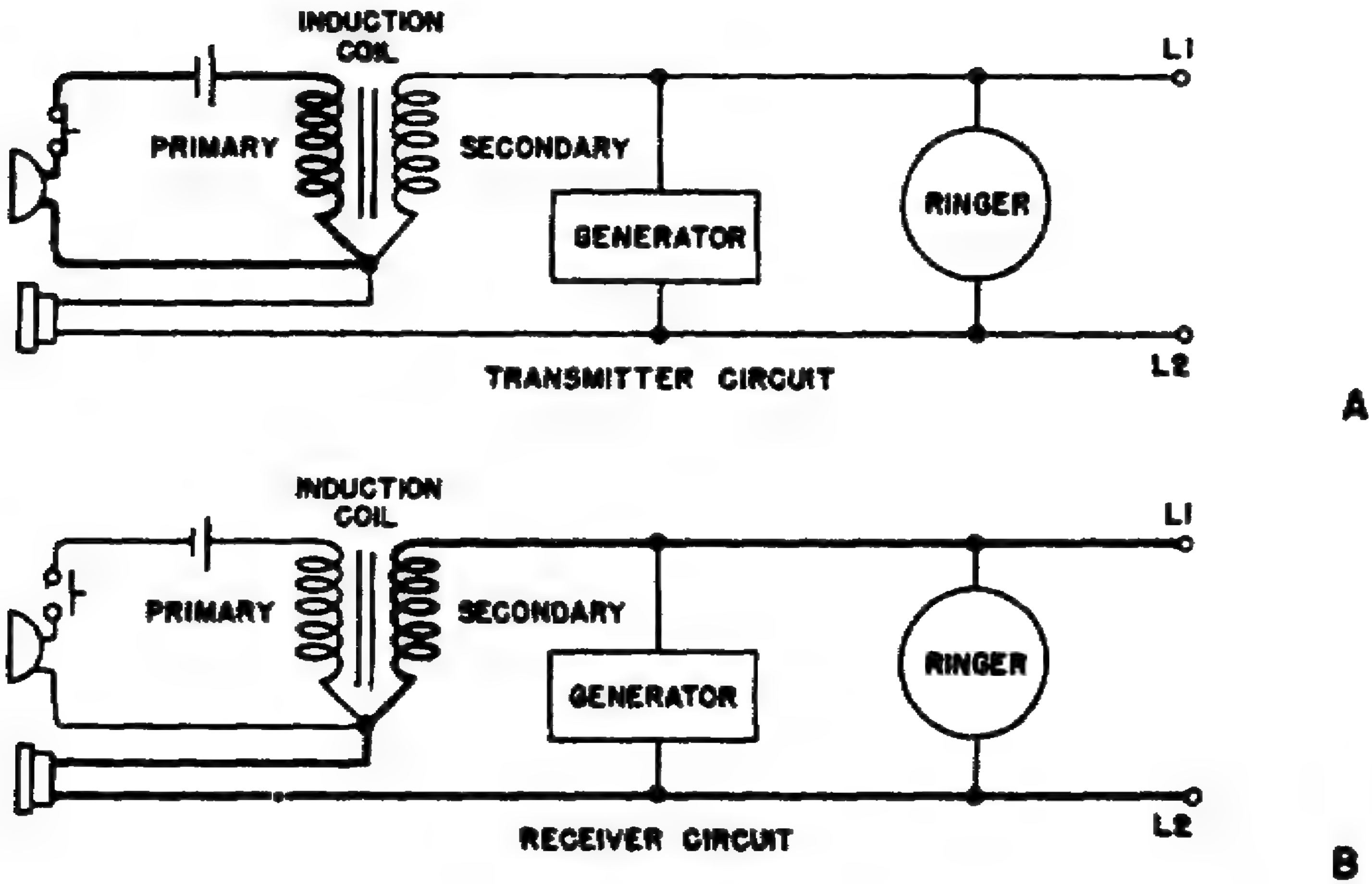


FIGURE 35. Local-Battery Telephone Set with Induction Coil.

42. <u>Principles of Induction Coil</u>.

a. Comparison with transformer. The induction coil is essentially a transformer. This similarity may be noted by comparing the circuit diagrams of the transformer and induction coil in figure 36. Electrically, the action of an induction coil is the same as that of a transformer, and the same basic principles apply to it. The transformer in its simplest form consists of two conducting coils which have mutual inductance between them. The common connection between the windings of the induction coil does not affect the mutual inductance between the coils. As a result of the mutual inductance, a varying current in one winding induces an ac voltage in the other. The value of the induced ac voltage depends on the turns ratio and on the rate at which the current changes: the higher the rate of change, the greater the induced voltage. The induced voltage has the waveshape of the changing current. This action of the transformer is explained in detail in TM 11-681.

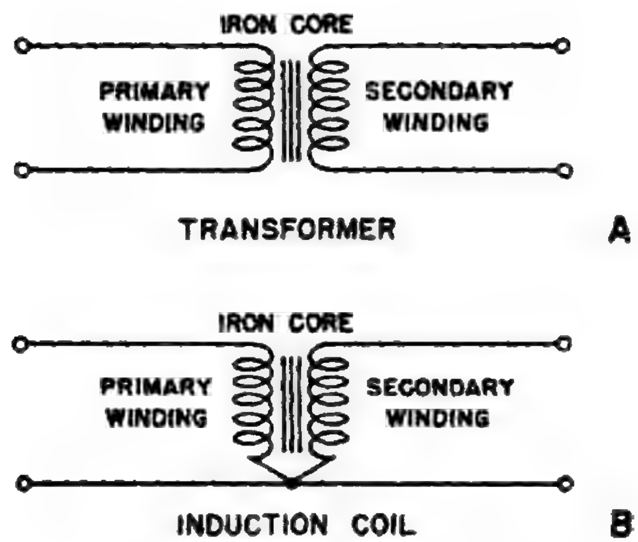


FIGURE 36. Comparison of Transformer and Induction Coil.

43. Summary.

a. The telephone set is the device supplied the telephone user to initiate and receive telephone calls. It has two principal circuits: the talking circuit, which provides an electrical path for the voice current, and the signaling circuit, which provides an electrical path for the signaling current. In the local-battery telephone set the components of the talking circuit are the transmitter, receiver, handset switch, battery, induction coil, and capacitor. The components of the signaling circuit are the hand generator and ringer.

b. The electrical energy for the voice current comes from the battery. A handset switch controls the battery current to the transmitter and thus increases the useful life of the battery. The handset switch, together with the transmitter and receiver, usually is mounted in a handset.

c. The induction coil, which is essentially a transformer, extends the range of the telephone set and improves its efficiency and performance. This it does by--

(1) Separating the transmitter and receiver current so that direct current from the transmitter does not pass through the receiver.

(2) Inducing a higher voice-current voltage in the secondary winding as a result of its step-up action as a transformer.

(3) Increasing the percent change in the resistance of the transmitter circuit.

CHAPTER 5

COMMON-BATTERY TELEPHONY

Section I. Basic Principles and Components of Common-Battery System.

44. Introduction.

a. The essential difference between the common-battery systems discussed in this chapter and the local battery systems discussed in chapter 4 is the number and location of the batteries which furnish the power to operate the system. A common-battery telephone system is one in which a centrally located storage battery is used in place of the individual dry cells required at each telephone station of a local-battery system. The single common battery serves all the stations of the system.

b. As might be expected, many of the components of common-battery systems are identical with, or at least very similar to, the corresponding local-battery components. In this chapter, such components are only briefly treated, and the similarities and differences between them and their local-battery counterparts are pointed out.

c. In order that a single battery may serve all stations in the system, it is necessary that the stations be in parallel with each other as far as dc is concerned, with the battery connected across the line instead of in series with it. It follows from this requirement that certain circuits and components of common-battery systems are different from their local-battery counterparts, and that certain other circuits, not used at all in local-battery systems, are included in a common-battery system. Such circuits, which differ materially from components discussed in earlier chapters, are explained fully here. In presenting the complexities of common-battery systems, the method followed is the same as that in chapter 4, starting with a highly simplified circuit incorporating only the barest essentials, and then adding components and auxiliary circuits one at a time as the need for them is developed. In the interest of clarity, it sometimes will be necessary to postpone the discussion of certain components when they first are mentioned until a later point, and therefore only by a careful reading of the entire chapter can the complete system, its components, and their functions and interrelations be understood.

45. General Features of Common-Battery System.

a. Advantages. The use of a single storage battery gives the common-battery system several important advantages over the local-battery system.

(1) The storage battery used in the common-battery system is much more economical to maintain than the dry cells of the local-battery system. Dry cells deteriorate and must be replaced periodically, whereas storage batteries can be recharged when necessary.

(2) The storage battery of the common-battery system gives a voice signal more uniform in amplitude, because it maintains a fairly constant voltage--more constant than the dry cells of the local-battery system.

(3) In the common-battery system, signaling is performed automatically when the receiver is lifted, eliminating the need for a hand generator and manual cranking, and making the equipment of the telephone set much simpler.

(4) In the common-battery system, the operator is signaled automatically upon completion of calls. This reduces the amount of supervision required, and allows a single operator to handle many more lines than is possible in a local-battery system.

(5) Finally, because the single storage battery is located at the telephone central office, inspectors are not required to make periodic visits to the associated telephone stations, as they must do in a local-battery system, to test dry cells for deterioration.

b. Limitations. In spite of its many advantages, the common-battery system has limitations and disadvantages that must be considered before giving it preference over the local-battery systems in certain applications.

(1) The common-battery system requires line construction of much higher quality than that required for the local-battery system, because current for the operation of the transmitter at the telephone set and supervisory relays at the central office must be supplied over the line.

(2) The lines of the common-battery system must be well balanced electrically, since unbalance in the wires of the outside plant impairs the quality of transmission and the distance over which transmission can be effected.

(3) Switchboard equipment in common-battery systems is much more complex and expensive than local battery equipment performing comparable functions, and it requires a greater time for installation and maintenance.

(4) The resistance of the loop or line to the common battery telephone station limits the distance over which talking and signaling currents may be supplied. Sufficient current must flow to assure operation of the following:

(a) The transmitter at the station.

(b) The line signal at the central office when the receiver is lifted.

(c) The supervisory relay at the central office when the receiver is hung up.

c. Applications. Because of the greater expense involved in the construction and maintenance of the inside and outside plant equipment of the stations and much local traffic are concentrated in a small area. In commercial practice, common-battery systems are used in all cities and large towns; in military applications, they often are used in higher headquarters. Local-battery systems are much better suited to rural areas where there are relatively few stations scattered over a large area; but they also are used for field military applications, for they provide better transmission over field wire than does the common-battery system. In general, common-battery systems have greater application in permanent installations.

46. Basic Circuits of Common-Battery System.

a. Simple common-battery circuit. The essential feature of a common-battery system is emphasized best by comparing the simplest possible common-battery system with the simplest possible local-battery system. The essential difference between the two systems is illustrated in figure 37.

(1) The figure 37A illustrates a very simple local-battery circuit, with hand generators and ringers omitted. The circuit consists of a transmission line terminated at each end by a telephone set. The telephone sets, A and B, are shown in elementary form and consist of a transmitter, a receiver, and induction coil, and a local battery.

(2) For purposes of comparison, an equally simple common-battery circuit also is illustrated. In this diagram, a common battery is shown connected across the telephone line, replacing the individual local batteries. Each telephone set consists of a transmitter, a receiver and an induction coil. Reference to the circuits will indicate one outstanding difference: In the local-battery circuit, the receiver and the secondary, S, winding of the induction coil are wired in series and connected across the line; in the common-battery circuit, the transmitter and the primary, P, winding of the induction coil are wired in series and connected across the line. A later paragraph describes more in detail the practical circuits used in common-battery systems.

b. Direct-current paths of simple common-battery circuit. As explained in chapter 3, direct current flows through the transmitter when it is operating. In the simple local-battery circuit, direct current is furnished by the local battery in series with the transmitter and primary winding of the induction coil at each station. In the common-battery circuit, however, direct current is furnished to both transmitters by the common battery, as shown in figure 37. The figure illustrates the direct-current path from the common

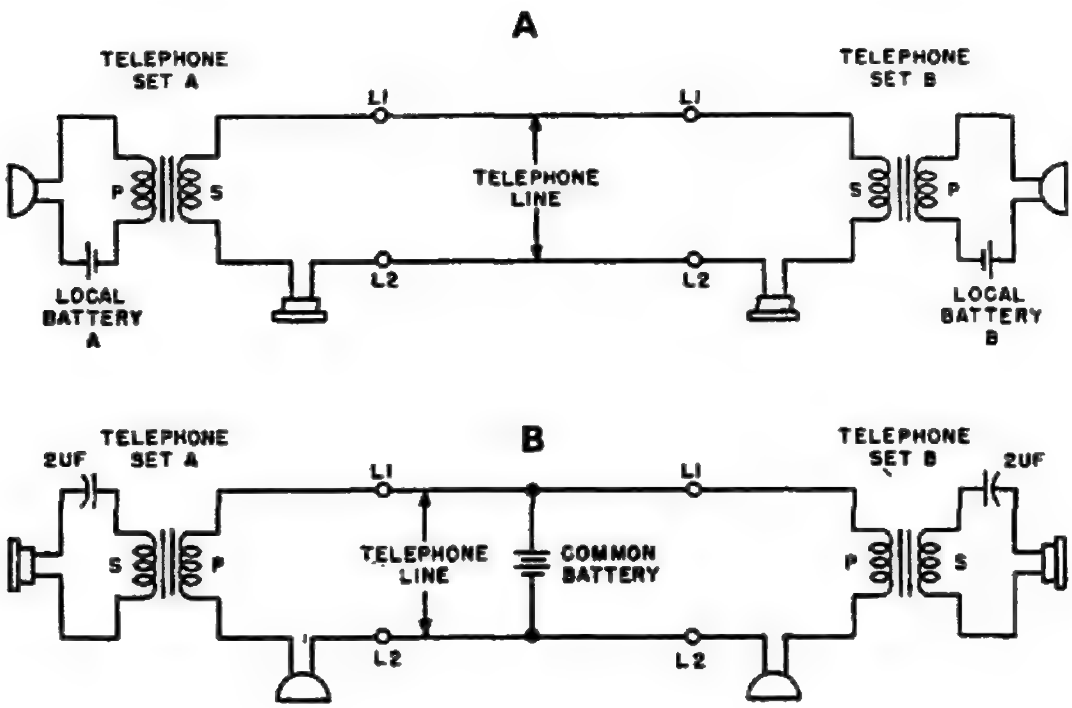


FIGURE 37. Comparison Between Simple Common Battery Telephone Circuits

battery to two telephone sets. It can be seen that, as far as direct current is concerned, the two telephone sets and their associated telephone lines are in parallel with respect to the common battery. If several telephone circuits were connected across the single battery, the direct current which the battery would be required to furnish easily could reach extremely large values. For this reason, the common battery in a common-battery system usually is connected permanently to a battery charger. The function and operation of a battery charger will be explained more fully in a later chapter.

c. Talking path in simple common-battery circuit.

(1) It has been shown (ch. 3) that the operation of a telephone transmitter is based on the principle that sound waves, striking the diaphragm of the transmitter, produce corresponding vibrations of the diaphragm. The varying pressure of the diaphragm varies the resistance of the carbon granules, and causes the current to fluctuate about its normal steady value. The resulting pulsating direct current therefore can be considered to consist of a steady direct current on which is superimposed a voice-frequency alternating current. The paths of the dc and ac components of the transmitter current are not necessarily the same.

(2) The talking path in the simplified common-battery circuit is shown in figure 37. At first glance it would appear that the two telephone sets are in series so far as the talking path is concerned. However, the common battery now must be considered in parallel with the receiver and transmitter of the listening station. Thus, if the person at station A is talking into his transmitter, the voice-frequency currents originating at transmitter A flow through the line until they reach the point where the common battery is bridged across the line. Since the impedance of the battery to the voice-frequency currents is much lower than that of the transmitter-receiver combination of station B, the major portion of the voice-frequency currents will flow through the battery leg. The same situation arises when the voice-frequency currents originate at the transmitter of station B. The battery, by shunting the receiver branch of the listening station, greatly reduces the magnitude of the voice-frequency currents flowing in the receiver.

(3) In order to prevent the common battery from shunting the receiver branch of the listening station, some component must be inserted in series with the battery in the battery leg to voice-frequency currents. This is

accomplished by the use of filter networks (fig. 38). The actual filter networks used in common-battery circuits are either retardation-coil or repeating-coil arrangements. Although the filters present a relatively high impedance to alternating currents, their dc resistance is so low that they do not affect materially the direct current from the battery to the telephone stations.

d. Practical common-battery circuits. In the following paragraphs, the simplified circuit explained above will be used as a starting point to outline the need for the various circuits and components used in practical systems. For example, the simplified circuits of figures 37 and 38 show only two telephone stations, and the common battery is bridged across the line. In practice, the system would include many more two stations, and any two stations would be connected through one or more switchboards or central offices. Also, in practice, the common battery is located at a central office, and is connected through a power distributing panel to the switchboard to the telephone stations when they are in use. Associated with the switchboard are various circuits required to develop the advantages of efficient operation of which the common-battery system is capable. The switchboard may be regarded as the heart of the system. Although the switchboard serves the same basic function in the common-battery system as in the local-battery system, the common-battery switchboard differs in many of its details from the local-battery switchboards discussed in chapter 4. Therefore, before proceeding with a full discussion of practical common-battery circuits, the common-battery switchboard will be described.

47. Common-Battery Switchboard.

a. Function.

(1) As in the case of the local-battery switchboard, the main function of the common-battery switchboard is to permit efficient connection of any two telephone stations connected to it. The switchboard also must provide means for supervision of calls, and must enable the operator to ring the called station. Most ringing is performed by ringing machines and circuits similar to those of a local-battery system.

(2) The efficient operation of a common-battery system is made possible by the various circuits contained in the switchboard. They include line circuits and cord circuits of various kinds, trunk circuits, ringing circuits, supervision circuits, and various auxiliary circuits.

(3) Although the circuits mentioned above seem to be of the same general types as those in a local-battery switchboard, they actually are different in many respects, primarily because of the difference in battery supply. The structure and operation of the circuits associated with common-battery switchboards, together with their interrelation and the role of the switchboard operator in making connections between telephone stations, are discussed in later sections of this chapter.

b. Types. Common-battery switchboards in general may be classified as nonmultiple and multiple.

(1) A nonmultiple switchboard is one in which each line connecting a telephone station to the switchboard terminates in only one jack. This type of switchboard obviously limits the number of lines that can be serviced by a single

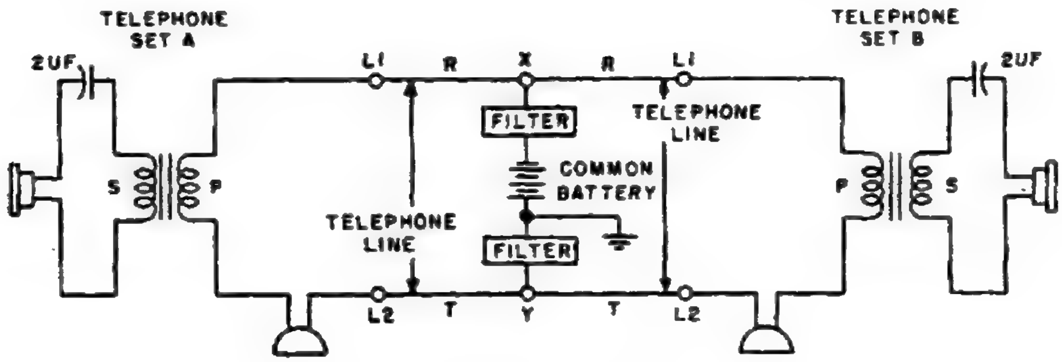


FIGURE 38. Simple Common Battery Circuit

operator, or even by several operators. It is obvious that it often might be necessary to connect a calling line terminating on a line jack located at one end of the switchboard to a called line terminating on a line jack at the other end, which would result in a confusing network of cords. For this reason, the use of nonmultiple switchboards is limited to systems that do not require more than three operators to handle the traffic.

(2) A multiple switchboard is one in which each line connecting a telephone station to the switchboard terminates in several line jacks, connected in parallel or multiple, at different points on the switchboard. This makes it

possible for the operator at each position of the switchboard to reach one of the line jacks of any calling or called station connected to the switchboard, greatly increasing the traffic which the switchboard can handle. The discussion which follows will concern itself with the description and operation of a nonmultiple common-battery switchboard.

c. Description of front of switchboard. In general, the equipment arrangement is similar in all cord-type switchboards, but it is not exactly the same. The switchboard in figure 39 can be used at a small central office.

(1) The illustration shows the vertical portion of the plugshelf, sometimes called the cordshelf, divided into two panels by the vertical separator through its center. The left panel carries 50 line (station) jacks with their associated line lamps, a supervisory pilot lamp, fuse-alarm lamp, and a line pilot lamp. The right panel has, in addition to 50 line jacks and line signals, a single row of jacks and signals to which exchange lines are connected.

(2) The plugshelf holds 15 pairs of cords and 1 single cord. The paired cords are used to complete interconnections. The single cord, when present, is used by the operator to advise a calling station when all the paired cords are in use. This single cord is not standard equipment on all switchboards.

(3) The switchshelf carries the control levers of the listening and ringing switches, the associated supervisory lamp signals, and the switchboard dial. Each pair of cords is associated with a pair of supervisory lamp signals and a pair of switches. The dial is used in completing connections between one of the switchboard stations and a station associated with a dial central office.

(4) The extreme left-hand cord (fig. 39) is the A (answering) cord of the first pair of cords. The cord immediately in front of that cord, toward the operator, is the C (calling) cord of the first pair of cords. The term answering cord means that on a station line signal this cord is used in answering the signal, leaving the C cord available for making connections to an exchange if this is required. This association of cords to lines is necessary to proper supervision. Calls to another switchboard station can be completed with the C cord. Answering and calling cords sometimes are referred to as back and front cords, respectively.

(5) The two lamp signals immediately in front of each pair of cords are the supervisory signals associated with these cords. The supervisory signal farthest from the operator is the A cord signal. The signal nearer the operator is the C cord signal. These signals inform the operator when one or another of the connected stations hangs up the receiver, or whether either station jiggles the hookswitch. The supervisory signals are discussed in more detail in later paragraphs.

(6) The switch levers shown on the switchshelf control the associated listening and ringing switches. Each pair of switches is associated with a pair of adjacent cords. Each switch lever may be placed in any one of the following positions: In any selected pair of levers, the lever farthest from the operator, when drawn backward toward the operator, operates the associated switch, which connects ringing power to the ring and tip of the A cord. Pushing the lever away from the operator establishes in the associated cord circuit a condition commonly referred to as a night connection. When the lever is vertical, the associated switch is in its neutral position. The lever nearer the operator, when moved away from the operator, connects the operator's telephone set to that particular cord circuit, permitting intercommunication among the operator and the stations connected by the cord circuit. When the lever is drawn toward the operator, ringing power is connected to the ring and tip of the C cord. Service at a switchboard sometimes requires that certain extension stations be connected to central-office lines during times while the switchboard is unattended, such as outside of regular business hours, and at night. This service can be provided in the usual manner by connecting the A cord to the extension station and the C cord to the central-office line. The act of connecting the C cord to the central-office line, however, automatically connects a bridge across the ring and tip cord conductors, and thus a signal appears at the central-office switchboard, even when the receiver is on the hookswitch at the extension station. The undesirable condition is corrected when the night-connection switch is moved to the operated position. This operation opens the bridge across the ring and the tip cord conductors and holds the central-office line open until the receiver is removed from the hookswitch at the extension station. This establishes the night connection.

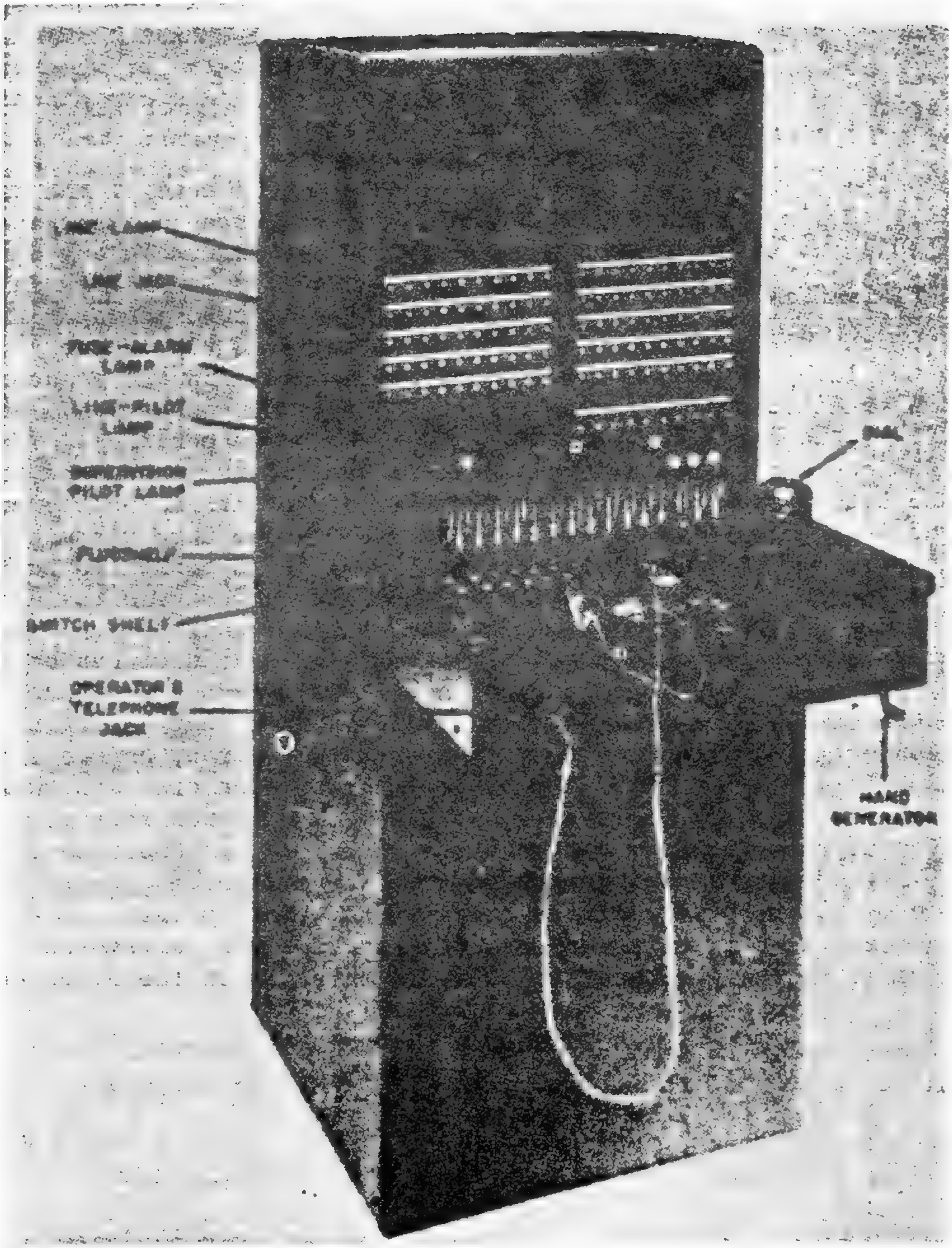


FIGURE 39. Typical Non-multiple Common Battery Switchboard.

(7) The vertical portion of the switchshelf carries the operator's telephone jack and the hand-generator crank. The operator's headset (transmitter and receiver) is corded to a plug. When this plug is inserted in the telephone jack, the headset is connected electrically into the switchboard circuits. Almost every switchboard is equipped with a hand generator. This generator is used for ringing the bells at the stations when the ringing power supply fails or when no other ringing power is available. The hand generator is operated by rotating the hand-generator crank in a clockwise direction. Operating a ringing switch while turning the hand generator crank connects ringing power to the associated cord.

NOTE: Access to parts of the switchboard apparatus and wiring is gained by removing a panel from the back of the board. Generally, this panel is removed by lifting upward and outward on the panel. Access to the switches shown on the switchshelf, operator's telephone jack, hand generator, and associated wiring is obtained by unlocking and raising the switchshelf. A special switchboard key is necessary to unlock the switchshelf.

48. Operation of Common-Battery Switchboard.

To make clear the main function of the switchboard in relation to the telephone lines and stations connected to it, a brief over-all picture of the operation of a common-battery switchboard is given in this paragraph. A number of important details, omitted here for simplicity, are described fully in later paragraphs. The present discussion covers a cord circuit and the telephone stations which it interconnects through the switchboard.

a. Cord circuit.

(1) Figure 40 is a simplified diagram of a cord circuit in a common-battery switchboard. This circuit consists of two cords, an answer cord and a call cord, each of which contains three conductors: tip (T), ring (R), and sleeve (S). The tip conductors of the two cords are connected, and their junction is connected to the positive (grounded) battery bus through a filter network (par. 46 and fig. 38).

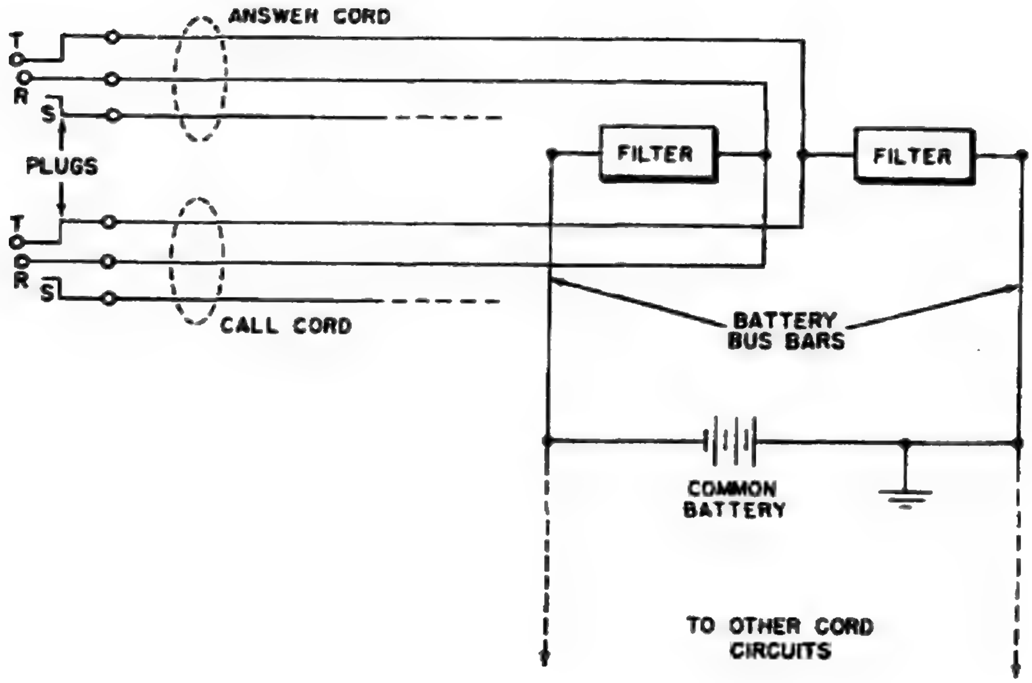


FIGURE 40. Simplified Common-Battery
Cord Circuit

Similarly, the two ring conductors are connected, and their junction is connected to the negative battery bus through a similar filter network. The sleeve conductors are shown not connected. Actually, they are used for connection to supervisory circuits.

(2) Each of the cords is connected at its free end to a plug containing three contacts. The contacts of the plug also are called tip, ring, and sleeve, from which the cord conductors connected to them derive their names. The plug at the end of the answer cord is called the answer plug, and is used by the switchboard operator in answering a call originating at the calling telephone station. The plug at the end of the call cord is known as the call plug; it is used by the operator to complete the connection to the called telephone station.

b. Line circuits.

(1) As in a local-battery system, a connection between two telephone stations in a common-battery system is completed by means of a cord circuit through the line circuits associated with the two telephone stations. In

figure 41, the line circuits are shown as consisting only of line jacks, one for each telephone line connected to the switchboard, into which the plugs of the cord circuits may be inserted by the operator. Actually, several kinds of line circuits are associated with common-battery switchboards, all of them including some means for signaling the operator automatically when a station wishes to make a call. Since the present discussion is concerned only with the basic elements of the common-battery system, however, consideration of the line circuits actually used in common-battery switchboards, including such necessary requirements as signaling and supervisory circuits, must be deferred. Note that the line jacks illustrated have three contacts, also called tip, ring, and sleeve, to correspond to the contacts of the plugs and the conductors of the cords.

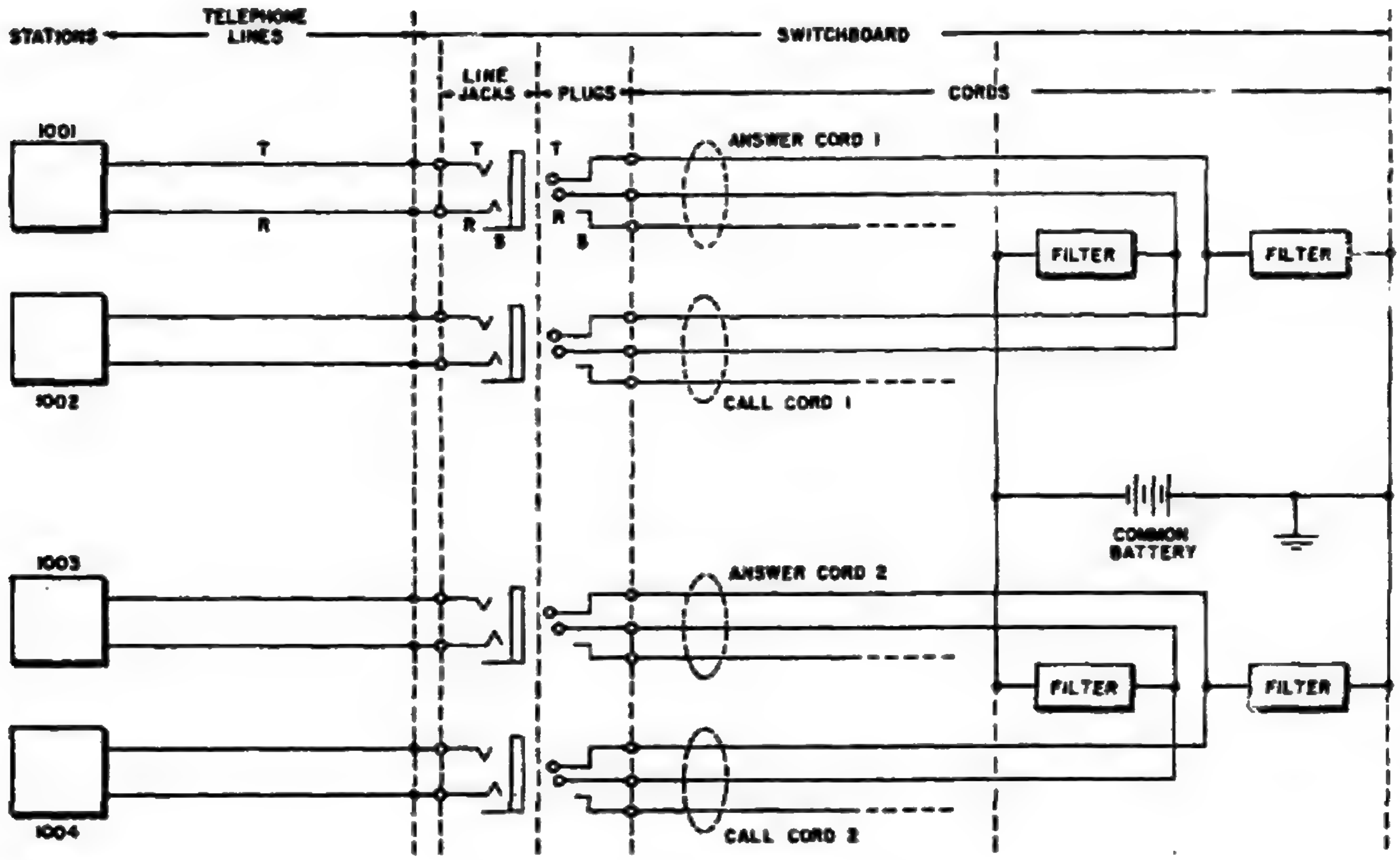


FIGURE 41. Simplified Common-Battery Cord and Line Circuit

(2) The tip and ring contacts of the line jacks are connected by wires to terminals on the rear panel of the switchboard. Since the telephone line from each telephone station is connected to one pair of these terminals, each telephone station has a direct connection to a line jack on the front panel of the switchboard. Figure 41 shows four telephone stations (numbers 1001 through 1004), each of which is connected by a separate telephone line to a jack on the switchboard. Also shown in the figure are two cord circuits, connected through their respective filter networks to the battery bus bars. All of the cord circuits contained in a switchboard are connected in this manner.

c. Tracing a call through switchboard.

(1) The progress of a call from station 1001 (the calling station) to station 1002 (the called station) through the switchboard is traced in figure 42. Again, the operation of the signaling and supervisory circuits is not considered in this introductory simplification. Assume that the operator is informed that station 1001 wishes to place a call. He inserts the answer plug of cord circuit 1 in the line jack connected to station 1001, in A. This causes the tip and ring contacts of the plug to make contact with the tip and ring springs of the line jack, as shown.

(2) The operator switches his telephone set into the cord circuit. He receives the number of the called station, 1002, from the calling station, and inserts the call plug of the same cord circuit used in answering the calling station in the line jack associated with station 1002, as in B. He then rings station 1002 and watches for the answer signal. (This is made known to the operator by means of the supervisory circuit associated with the cord circuit, as explained later.) When station 1002 answers the ring, the ringing is stopped.

(3) A talking path now is established between station 1001 and station 1002. The path is from station 1001 over the tip side of the telephone line to the tip contacts of the associated line jack and the answer cord; through the tip conductors of the answer and call cords to the tip contacts of the call plug and the line jack of station 1002; over the tip side of the telephone line of station 1002 to the telephone set of station 1002; over the ring side of the telephone line of station 1002 to the ring contacts of the associated line jack and the call plug; through the ring conductors of the call and answer cords to the ring contacts of the answer plug and the line jack of station 1001; and, finally, over the ring side of the telephone line of station 1001 to the telephone set.

(4) The filters in series with the battery leg prevent the flow of talking current through the battery. Besides preventing the battery from short-circuiting the talking current to the listening station, they prevent the various cord circuits from interfering with each other. For example, suppose a conversation is in progress between telephones 1003 and 1004 by way of cord circuit 2, as in B, in addition to the conversation between telephones 1001 and 1002. If no filters were present in the cord circuits, talking current originating at any of the four stations theoretically could flow in the receivers of all of the other stations. This, of course, would make impossible a private conversation between only two stations.

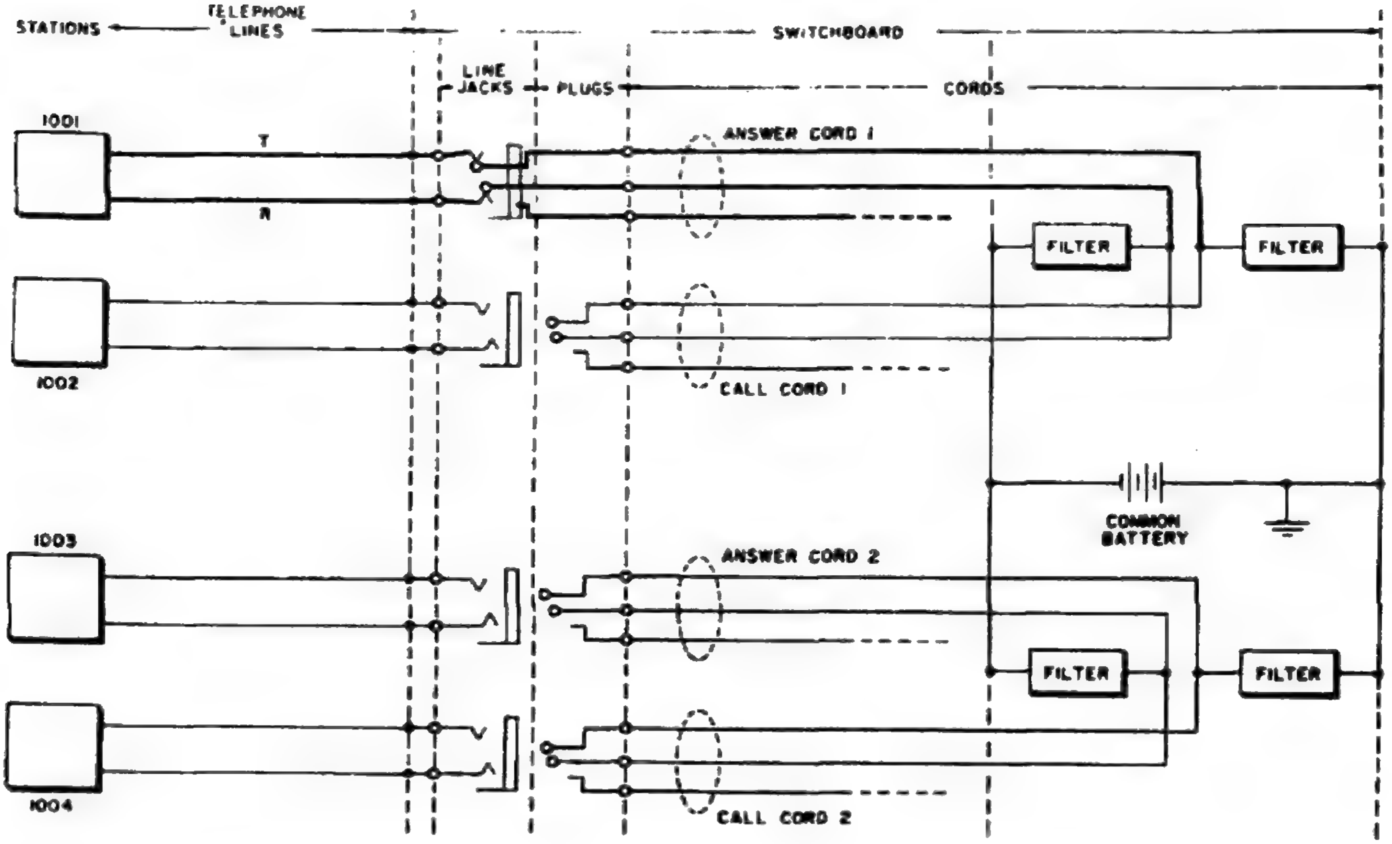
(5) With the circuit arrangement shown in B, however, it is possible for any two stations to have a private conversation, without interference from any other conversations that might be in progress by way of the other cord circuits. For example, if station 1001 wishes to converse with station 1003, the answer cord would be connected to the line jack of station 1001, and the calling cord would be connected to the line jack of station 1003. The cord circuits in the switchboard therefore provide a rapid and efficient means of interconnecting the various lines terminating on the switchboard, each cord circuit accommodating a conversation between any two stations.

(6) Figure 39 shows that, although the switchboard has 100 line jacks and lamps accommodating 100 telephone stations, it has only 15 cord circuits and an additional answer cord (located at the extreme right of the plugshelf). This enables the switchboard to handle up to 15 individual calls at any one time, so that this particular switchboard would be used in a common-battery system where the traffic normally would be not more than 15 calls at any one time. The additional answer cord (not found on all switchboards) is used to notify a calling telephone that all the regular cord circuits are busy when that situation arises.

49. Basic Components of Common-Battery Cord and Line Circuits.

a. Common-battery cords and plugs.

(1) The functions of the cords and plugs of the cord circuits in common-battery systems, as explained above, are essentially similar to those associated with local-battery systems. In addition to providing connections between a calling and a called telephone for talking and signaling, however, common-battery cords and plugs provide a means of automatic supervision through their respective sleeve conductors and contacts.



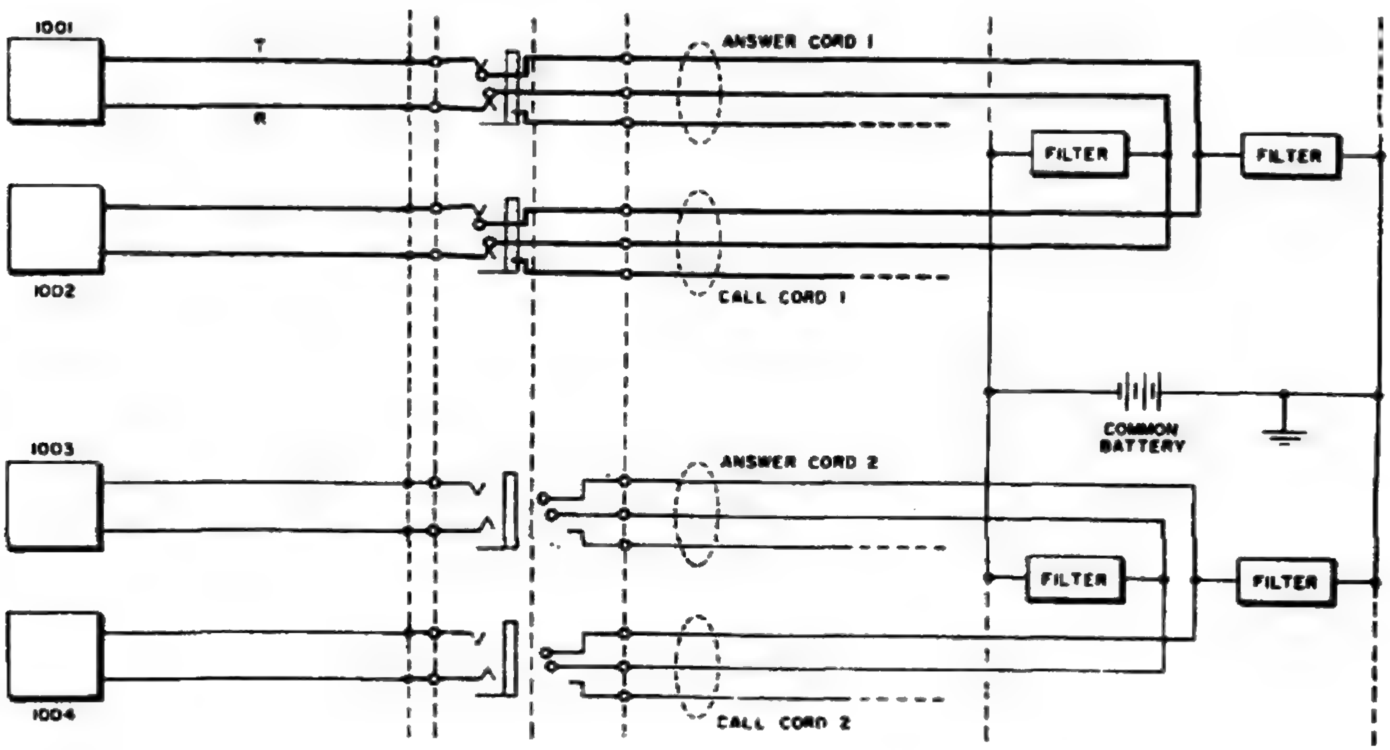


FIGURE 42. Tracing a Call from Station 1001 to Station 1002.

(2) Figure 43 illustrates a common-battery cord connected to a plug. Its general appearance is similar to the local-battery cord. The common-battery cord, however, instead of having only two conductors, has three. As mentioned previously, the conductors of a common-battery cord are the tip (white wire), ring (blue wire), and sleeve (red wire), and they are connected at the free end of the cord to the corresponding terminals (tip, ring, and sleeve) of the plug.

(3) The other ends of the cord conductors are soldered or clipped to individual metal lugs and connected to terminals in the interior of the switchboard which connect the cords to the remainder of their respective cord circuits. The tip and ring of the cord and plug connect the line wires from the telephone stations to the cord circuit by way of the various line jacks.

(4) Each cord conductor consists of fine tinsel threads and is insulated with a layer of silk floss covered by cotton braid of the proper identifying color (white, blue, or red). As in the case of the local-battery cord, a strain cord also is provided which has the same function as the strain cord of the local-battery switchboard.

b. Common-battery line jacks.

(1) The line jacks shown in figures 41 and 42 are called simple jacks. They have three contacts--tip, ring, and sleeve--to correspond to the contacts of the plug and cord. It will be remembered that the local-battery jack has only two contacts--tip sleeve. The tip and ring contacts of the simple common-battery line jacks are spring-type contacts. They make contact with the tip and ring contacts of the plug when a plug is inserted in the jack.

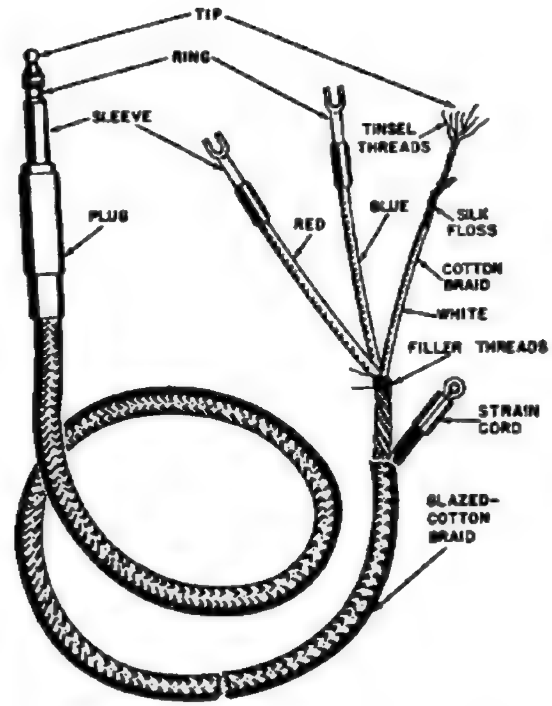


FIGURE 43. Common-Battery Switchboard Cord and Plug.

The tip and ring wires of the telephone line, with which the jack is associated, are connected to corresponding terminals on the rear of the switchboard, and the tip and ring of the line jack are connected respectively to the same terminals, as explained previously. The sleeve of the line jack is tubular, and makes contact with the sleeve of the plug.

(2) Another type of line jack, is called a cut-off jack. This type of line jack has two auxiliary contacts in addition to the regular tip, ring, and sleeve contacts. When no plug is in the jack, one auxiliary contact lies against the tip spring of the jack, and the other against the spring ring. This provides a means of connecting an auxiliary circuit, such as a lamp circuit, to the tip and ring of the jack through the auxiliary contacts, as will be explained later. When a plug is inserted in the jack, as shown in the figure, the tip and ring contacts of the jack are spread farther apart, away from the auxiliary contacts, breaking or cutting off the auxiliary circuit. Although the cut-off jack provides a simple means of connecting an auxiliary circuit to the tip and ring contacts of the line jack, it has a serious limitation. Since the main and auxiliary contacts are contained within the jack, they are not readily accessible for adjustment. Special tools must be used, and, even with such tools, adjustments must be made without possibility of observing the effect produced, unless the jack is removed from the panel. A means of overcoming this limitation will be discussed later.

(3) Line jacks are mounted individually or in strips of 10 or 20, according to the type of switchboard in which they are used. The switchboard illustrated in figure 38, for example, has its line jacks mounted in strips of 10.

c. Common battery signal lamps.

(1) The line signal used in common-battery switchboards is usually a small lamp, instead of a ring-down drop, the drop-shutter mechanism used in local-battery switchboards. A typical signal lamp is illustrated in A, figure 44. It contains two filament terminals, small metal plates extending along opposite sides of the glass bulb, to which the filament wires from inside the bulb are soldered. A small wooden or bakelite block, cemented to the rear end of the lamp, supports and insulates the filament terminals. The glass bulb is tubular in shape to permit easy insertion of the lamp in the switchboard panel. In B, the lamp is shown in the position of a line lamp. A lamp of similar type is used for supervisory signaling.

(2) Because the line lamp is associated closely with the line jack, it usually is mounted in the switchboard panel as part of the same unit with its associated line jack, as in B. Here, a signal lamp is shown in a two-contact lamp jack below its associated line jack. After the lamp is inserted in its jack, the lamp entrance opening in the panel is closed with a glass lamp cap, or opal, as shown. The lamp cap may be color-coded to indicate that a particular line shall receive priority in the matter of prompt service or that the station is equipped to dial its own calls. Lamp jacks, like line jacks, are mounted either individually or in strips of 10 or 20, and they are located either directly below or directly above their respective line jacks. The lamps illustrated in the switchboard of figure 38 are located above the corresponding line jacks.

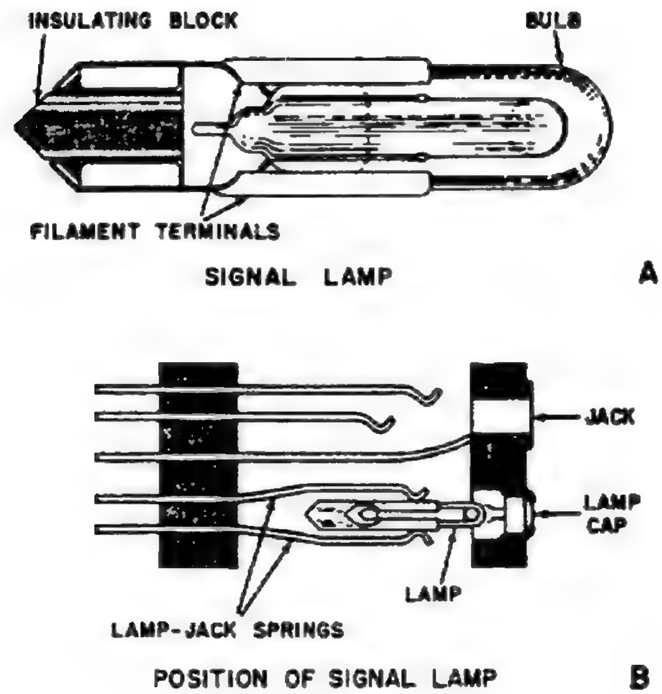


FIGURE 44. Structure and Position of Signal Lamp.

50. Common-battery Telephone Sets.

Telephone sets in common-battery system contain most of the same components that are in the local-battery telephone sets. The circuits connecting these components, however, differ considerably in the two systems. For this reason, the telephone sets in figures 41 and 42 are shown only in block diagram form. It is now appropriate to consider the circuits of common-battery telephone sets in detail.

a. Basic circuit of common-battery telephone set.

(1) The circuits of common-battery telephone sets may be classified as sidetone, or booster circuits, sidetone-reduction circuits, and antisidetone circuits. All three types, however, are understood best by considering first a simpler and more fundamental circuit, basic to them all (fig, 45). Each telephone set contains a transmitter, a receiver, an induction coil, I, with

a primary winding, P, and a secondary winding, S, a ringer, RG, a capacitor, C, and a hookswitch, H. Each telephone set has a circuit similar to the circuit of a local-battery telephone set except for these differences: There is no battery or hand generator in the common-battery set, and the handswitch shown is replaced by a hookswitch in the common-battery set. (In a local-battery system, the hand generator is needed to signal the operator. In a common-battery system, the switchboard operator is signaled automatically by the operation of the hookswitch.)

(2) The primary and secondary windings of the induction coil are shown in figure 45 as separate windings. This representation, although not important for the discussion of the operation of the basic circuit of figure 45, must be used in connection with the explanation of some of the other circuits which will follow.

(3) The theory of operation of the several components of a common-battery telephone set--transmitter, receiver, inductions coil, capacitor and ringer--is the same as that of corresponding components of a local-battery telephone set.

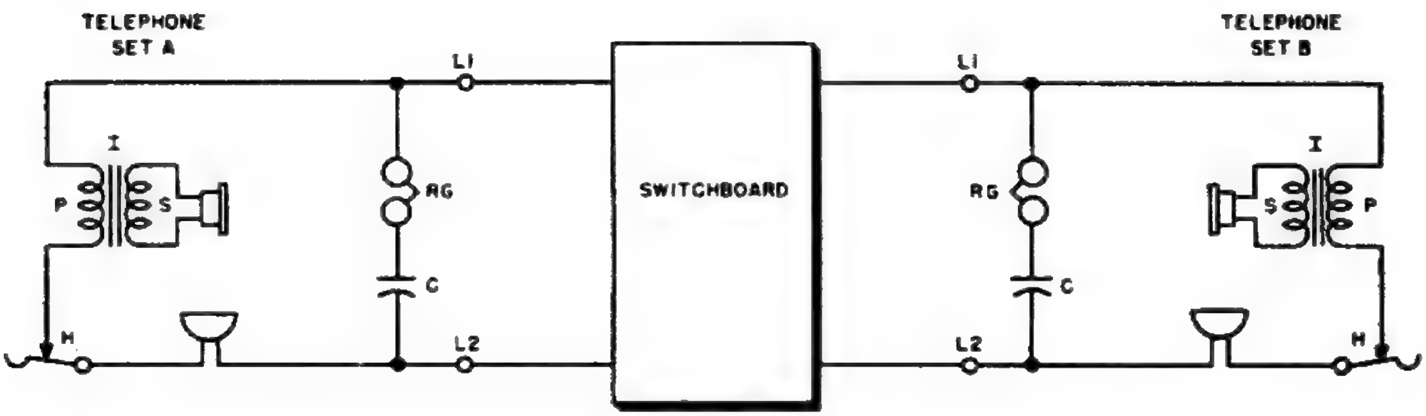


FIGURE 45. Basic Circuit of Common-Battery Telephone Set.

Their relation to each other and to the other components of the circuit differ in a common-battery system.

b. Operation of basic circuit. The basic simplified circuit of a common-battery telephone set (fig. 45) can be considered conveniently in three parts: the primary, or transmitter circuit, the secondary, or receiver circuit, and the ringing circuit.

(1) The primary circuit of a telephone set, shown in the figure, consists of the transmitter in series with the primary winding of induction coil I, hookswitch H, and line terminals L1 and L2. The hookswitch, as explained in (3) below, closes this circuit whenever the receiver is lifted from its hook or cradle, as when a user lifts it to make or answer a call. The battery at the central office may be considered connected effectively to terminals L1 and L2, on answering a call, by means of the cord circuit, line jack, and telephone line. When the hookswitch contacts are closed, direct current from the common battery flows through the primary winding of the induction coil and the transmitter. Words spoken into the transmitter cause a pulsating direct current to flow through the primary winding of the induction coil and over the line. A similar telephone set, at the calling station, is connected to this set, and the similar pulsating direct current flows through the primary winding of its induction coil. By transformer action, an alternating current flows in the secondary winding of the induction coil of the called set and in its receiver, where the sound waves striking the calling transmitter diaphragm are reproduced.

(2) The secondary circuit consists simply of the secondary winding of the induction coil in series with the receiver. It has been explained above that the pulsating direct current in the primary winding of the induction coil of the called set causes an alternating current to flow in the secondary winding and the receiver of the called set. However, by the same transformer action, the pulsating direct current in the primary winding of the induction coil of the calling set also causes a corresponding alternating current to flow in the secondary winding and the receiver of the calling set. This results in the production of an appreciable amount of sidetone so that the speaker hears his own voice in his own receiver. This undesirable effect is minimized by the use of circuits described below (pars. 51 through 53).

(3) Because the battery of a common-battery system is located at the central office, and is therefore always in the circuit, some means must be provided for making the circuit when a conversation is to be started, for keeping it closed while the telephone sets are in use, and for breaking or when the telephone conversation is over. This function is performed by a hookswitch in series with the primary circuit (fig. 45). The receiver in a common-battery set hangs on the hook of the hookswitch when not in use, and its weight keeps the hookswitch contacts normally open. Removal of the receiver causes the hookswitch contacts to close. Unlike the handswitch of the local-battery switch set, which may be the type that is pushed for talking and released for listening, the hookswitch contacts of a common-battery set remain closed during the entire conversation.

c. Ringer circuit. The ringer circuit of the basic common-battery telephone set consists of a ringer in series with a capacitor, usually of .5- f capacity. The combination is connected directly across the line, between terminals L1 and L2. The capacitor, in the common-battery set, blocks the flow of direct current through the ringer, but permits the flow of ringing current. The ringer does not shunt the primary circuit of the set appreciably so far as talking current is concerned, because the impedance of the ringer path to voice frequencies is much greater than that of the primary winding of the induction coil.

51. Common-Battery Sidetone (Booster) Circuit.

a. Arrangement. The basic circuit of a common-battery telephone set has been found (par. 50b) to produce considerable sidetone in either receiver. A more efficient circuit which, although it also produces sidetone, represents a considerable improvement over the basic circuit of figure 45 is the so-called booster circuit (fig. 46). It contains the same components as the telephone set shown in figure 45, but they are arranged differently. In this circuit, the receiver and the secondary winding of the induction coil are connected in series between the junction of the ringer and capacitor at A and the upper hookswitch contact, which is electrically the same as B when the hookswitch contacts are closed. Although this arrangement permits some direct current to flow through the ringer and the receiver, the high resistance of these components makes the amount small.

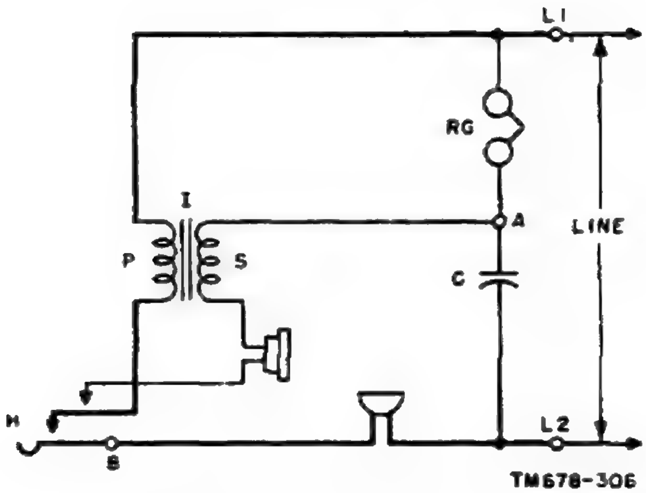


FIGURE 46. Arrangement of Common-Battery Sidetone Circuit.

b. Transmitting circuit. When hookswitch H is closed, dc voltage from the central office battery is applied to the components of the telephone set shown in figure 46. Application of this dc voltage produces a dc current flow in two paths. One current path (path 1) is through the primary of induction coil I, hookswitch H, and the transmitter. The other dc path (path 2) is through ringer RG, the secondary winding of the induction coil, the receiver, the hookswitch, and the transmitter. The amount of direct current flowing through path 2 is less than that through path 1 because of the higher ohmic resistance of path 2.

(1) When a voice-frequency sound activates the diaphragm of the transmitter and disturbs the position of the carbon granules in the transmitter, the current in the two paths varies in accordance with the frequency and amplitude of the sound wave. As a result, a voice-frequency component of current is developed through path 1 and the line, with voice-frequency voltages appearing across the transmitter and the primary winding of the coil. Little voice current flows through path 2, because the voice current through this path is limited by the high impedance of the ringer as compared to the impedances of the receiver and secondary winding. However, voice current in the primary winding through path 1 induces, by transformer action, a voice current in the path comprised of the secondary winding, the receiver, the hookswitch, the transmitter, and the capacitor.

(2) The connections to the primary windings of the induction coil are made so that the primary and secondary currents are in phase with each other. As a result, the primary and secondary currents combine in the common impedance presented by the transmitter, and the resultant voice current sent out over the line is boosted to a higher level. Also, the increased secondary current produces a larger local receiver current, and a high level of sidetone is obtained.

c. Receiving circuit.

(1) When the circuit is used for receiving, its operation is slightly different from that described above. Suppose that a voice current is being received from the line and enters the circuit through terminals L1 and L2 (fig. 46). This current will pass through path 1, and will induce a voice voltage across the primary winding and across the transmitter, the diaphragm of which is now at rest. The received current will not enter path 2 because of the high impedance of ringer RG. Because of this condition, it might at first appear that no output would be obtained from the receiver unit. However, this is not the case, because of inductive coupling between the windings of the induction coil. By transformer action, the primary current produced by the received signal induces a voltage into the secondary circuit consisting of the secondary winding, the receiver, the hookswitch contacts, the transmitter, and capacitor C. Voice current flowing through the receiver unit provides reception of the incoming signal.

(2) Again, a booster, or regenerative action is produced by the in-phase connections of primary and secondary windings of the induction coil, and these currents add in the common impedance presented by the transmitter.

d. Circuit efficiency. The over-all performance of the booster circuit is characterized by high efficiency. The chief disadvantage of the circuit is the presence of a high level of sidetone.

52. Common-Battery Sidetone-Reduction-Circuit.

a. Arrangement. A circuit that reduces the amount of sidetone produced in the receiver of its telephone set is the sidetone-reduction circuit (fig. 47). It is like the booster circuit of figure 46, except that here the transmitter is connected in series with the primary winding of the induction coil on the opposite side of the hookswitch contacts, as shown.

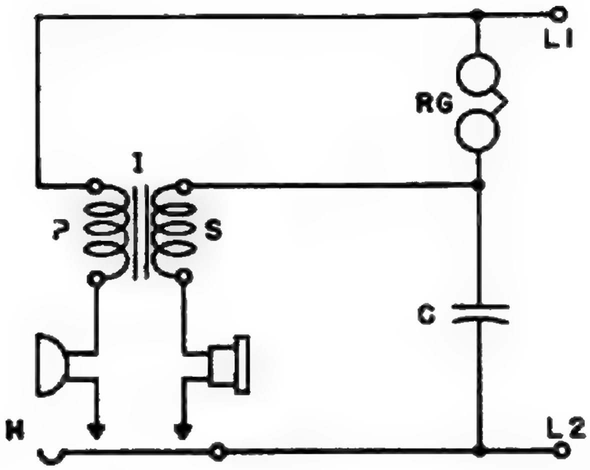


FIGURE 47. Common-Battery Sidetone Reduction Circuit.

b. Operation.

(1) Since the resistance primary circuit of figure 47 is approximately the same as that of the sidetone circuit described in paragraph 47, both the direct current from the central office battery and the voice-frequency currents corresponding to the sound waves striking the diaphragm of the transmitter are similar to those in the sidetone circuit. In this circuit, however, because of the different location of the transmitter with respect to the receiver, all of the voice current originating in the transmitter flows in the primary winding of the induction coil, and only by induction in the receiver circuit. The impedance of the ringer to voice-frequency current flows through the circuit comprised of the ringer and capacitor or the ringer, secondary winding, and receiver.

(2) The current fluctuations in the primary winding of the induction coil induce a corresponding alternating emf in the secondary winding. The primary and secondary currents are in phase because of the transformer connections, but little reinforcement of current occurs because there is no impedance common to primary and secondary circuits. As a result, sidetone is reduced.

(3) Although the sidetone-reduction circuit is effective in reducing the amount of sidetone, it lacks the desirable feature of the sidetone circuit--that of causing a higher voltage to be impressed on the line by booster action. For this reason, transmission with the sidetone-reduction circuit is less efficient than with the booster circuit discussed in the preceding paragraph.

53. <u>Common-Battery Antisidetone Circuit</u>.

a. Arrangement. As already explained, a high level of sidetone is undesirable in telephone receivers. It produces interference when the set is operated in noisy locations, and usually makes the user lower his voice when he hears his spoken words reproduced loudly by his own receiver, thus reducing the output of his transmitter to the line. Both of the common-battery sets discussed in paragraphs 51 and 52 produce sidetone. An antisidetone circuit which reduces sidetone to a very low level is illustrated in figure 48. The actual circuit diagram, in A, shows a three-winding induction coil. The primary circuit consists of a single primary winding, P, in series with the transmitter. The secondary circuit consists of two secondary windings, S and B, with a resistor, N, connected between them. The receiver is connected across the series combination of the resistor and secondary winding B, as shown.

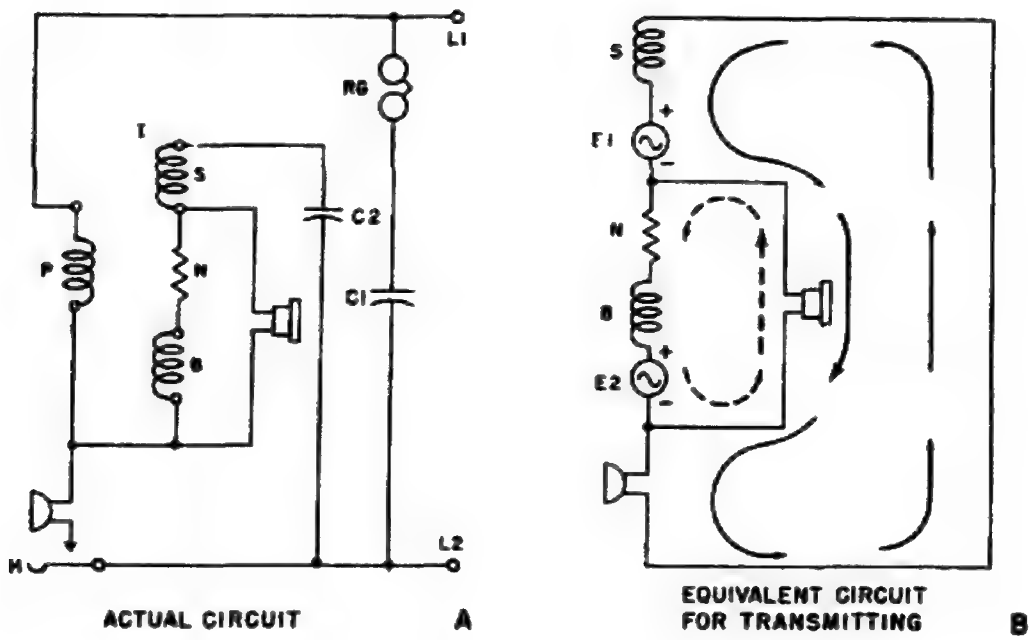


FIGURE 48. Common-battery Anti-Sidetone Circuit.

b. Operation of circuit.

(1) The operation of the antisidetone circuit shown in A can be understood by referring to its equivalent circuit for transmitting, in B. Voice currents originating in the transmitter flow in the primary coil, P, inducing voltages in both secondary windings. These voltages are represented in B by the ac generators--E1 for the voltage induced in winding S, and E2 for winding B. Voltage E1 causes a current to flow through the parallel combination of the receiver shunted by winding B and resistor N, through the transmitter and back to winding S through the capacitor (omitted from B, since it is practically a short circuit to voice-frequency currents). A portion of this current, of course, flows through the receiver in the direction shown by the unbroken arrows. At the same time, voltage E2 causes a current consisting of the receiver, resistor N, and winding B, in the direction of the broken-line arrows. The two currents through the receiver flow in opposite directions. By proper choice of the resistance of resistor N, the current caused by E2 is made exactly equal to the current through the receiver caused by E1. The two currents thus cancel, or balance, each other through the operation of balancing winding B, and no sidetone is produced.

(2) Actually, the circuit shown in figure 48 gives a perfect balance at only one frequency in the voice-frequency range. However, sidetone is reduced greatly over the entire telephone frequency range with this circuit. It is only one of several antisidetone circuits that have been developed in recent years.

(3) In receiving from a distant station, the operation of the receiver circuit in figure 48 is similar to that in figure 45, and is not affected by the antisidetone feature.

54. <u>Summary of Basic Principles and Components</u>.

a. Common-battery systems use a centrally located storage battery in place of the individual dry cells at the telephone stations in local-battery systems. The common battery is actually an auxiliary source of power, the main source being either a motor-generator set or a rectifier system.

b. The common battery gives a common-battery system certain advantages over a local-battery system, including automatic signaling and simpler supervision and maintenance. However, they can be used efficiently only where the traffic is heavy enough to warrant the relatively high construction and installation costs.

c. The two important paths in a common-battery system are the direct current path, for which the two telephone stations are in parallel with respect to the common battery, and the talking path, which does not include the battery. Filter networks are used to prevent the battery from short-circuiting the listening station.

d. Common-battery switchboards, like local-battery switchboards, are used to permit efficient connection of any two telephone stations connected to the switchboard. However, because of the difference in battery supply, there are differences between the circuits contained in common-battery switchboards and those in local-battery switchboards.

e. Nonmultiple common-battery switchboards are arranged so that each incoming telephone line terminates in only one line jack of the switchboard. This restricts the use of such switchboards to systems where no more than three operators are required to handle the traffic. The switchboard contains all the signal, supervisory, and pilot lamps, the line jacks, the cord and plugs, and the various switches and relays necessary for efficient operation.

f. Common-battery cords have three conductors--tip, ring, and sleeve. Common-battery plugs have corresponding elements to which the conductors of the cord are connected. Cords normally are plugged; one, the answer cord, is used in answering a calling station; the other, the call cord, for completing the call to a called station.

g. Simple common-battery jacks have three contacts--tip, ring, and sleeve, corresponding to the three conductors of a common-battery cord. Cut-off jacks have two or more auxiliary contacts associated with the tip and ring contacts. The auxiliary contacts either can be made or broken by the movements of the jack springs.

h. Line signals in common-battery systems are line lamps, mounted on the panel of the switchboard above or below their associated line jacks. Supervisory signals are lamps associated with the cord circuits.

Section II. Major Common-Battery Switchboard Circuits.

55. Telephone Relays.

a. Application of relays to telephony. As explained in paragraph 45, one of the important advantages of common-battery systems over local-battery systems is the provision of automatic signaling and supervision. This is made feasible by the use if a control device called a relay. The principles of

relays are explained in this paragraph before proceeding to a detailed discussion of the switchboard circuits which they control.

b. Definition of relay. A relay, as used in telephone circuits, is an electrically operated switch by means of which one switchboard circuit can be made to control the operation of one or more other switchboard circuits; in some cases the use of a relay enables a circuit to regulate or control its own operation. The basic operation of a relay is similar, therefore, to that of a manually operated switch, except that a relay is automatic in its operation.

c. Structure of typical relay.

(1) Although there are many different types of relays, differing in the details of their construction, operation, and application, the principle of operation is the same for all, and structural features are similar. Consider therefore what might be called a typical relay, illustrated in figure 49.

(2) The essential components of any relay include an armature, the motion of which opens and closes the circuit or circuits to be controlled, and one or more windings, through which the control current flows. The core on which the windings are placed is composed of a magnetic material such as silicon steel or permalloy. The number and types of the windings depend on the particular function of the relay.

(3) Associated with the armature are an armature spring and one or more contact springs. Each spring has one or more contacts made of pure silver, some silver alloy, or alloys or platinum or other metals. The contacts are arranged to be either open normally, as in figure 49, or closed normally; or, in relays with several contacts, some contacts may be open normally and others may be closed normally.

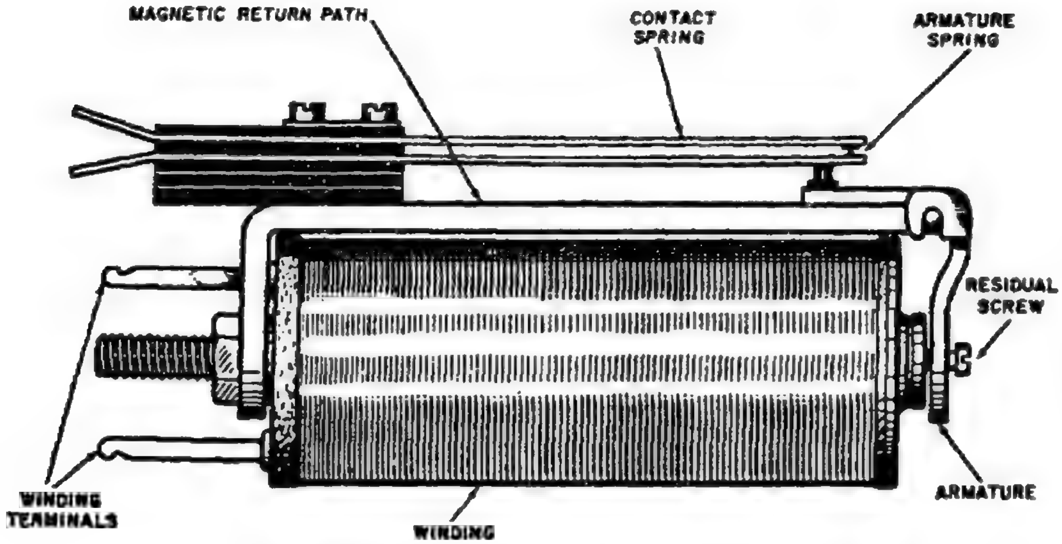


FIGURE 49. Structure of Typical Telephone Relay

(4) In the armature of some relays (fig. 49) there is a small setscrew, called a residual screw. It is used to prevent the armature from sticking to the core because of its residual magnetism, and can be adjusted for proper operation as required.

(5) To protect them from mechanical injury, and also to keep out dust and dirt, relays usually are provided with covers (not shown in the figure), often made of a nonmagnetic material so that they do not interfere with the operation of the relays. Some newer types of relays are sealed hermetically in an atmosphere of dry, inert gas, such as neon or argon. This protects them from the harmful effects of moisture, ice, fungi, acid, salt spray, and sand, and assures continuously uniform performance under varying conditions. They are becoming popular in military applications of equipment, especially for foreign service.

(6) Telephone relays are mounted at the rear of the switchboard, either singly or in groups, depending on their particular function, or on the circuits with which they are associated. Relay covers may be designed to cover only one relay or several relays of a group.

d. Operation of relays.

(1) A relay is really an electromagnet when current flows through its winding. The magnetic field around the core causes the armature to be attracted to the core. As it moves on its pivot, the armature causes the armature spring to be pushed up, moving the contact springs to open or close the various circuits controlled by the relay. When the circuit of the relay winding is broken, the magnetic field collapses, permitting the armature to spring back to its original position and restoring the relay contacts and springs to their normal position.

(2) The number and arrangement of contact springs which a relay may have depend on its application in a particular circuit, and on the power available to move the armature and the springs. The force with which the armature is attracted is proportional to the strength of the magnetic field, which, in turn, depends on the number of ampere turns of the electromagnet. This can be made large by using either a winding of many turns and a small current, or a winding of fewer turns and a large current.

(3) When a relay is connected in series with other circuit components, the current available to operate the relay depends on the total resistance of all the components in series, and tends to be relatively small. The winding (or windings) of the relay therefore should have a relatively low resistance but a sufficient number of turns to operate the relay properly. When relays are connected across the battery, however, it is necessary to "increase" the resistance of the windings in order to limit the current to a safe value. This usually is done by adding some German silver wire, or some high-resistance wire, to the regular relay windings.

LESSON 2 EXERCISES

In each of the following exercises, select the ONE answer that BEST completes the statement or answers the question. Indicate your solution by circling the letter opposite the correct answers in the subcourse booklet.

1. One way to simplify the maze of wires used in the telephone system shown in figure 26B is by using a centrally located:

a. trunk.

b. ringer.

c. switchboard.

d. hand generator.

2. The transmission lines interconnecting the telephone central offices of different exchanges are called:

a. trunks.

b. long lines.

c. field wire.

d. connecting cord.

3. The local-battery telephone set shown in figure 28 consists of several closely related circuits. The components necessary for a complete talking circuit between two telephones include the:

a. transmitters, receivers, batteries, and ringer.

b. transmitters, receivers, batteries, and connecting lines.

c. batteries, transmitters, receivers, ringer, and connecting lines.

d. batteries, ringers, transmitters, receivers, and a generator.

4. The telephones of a local-battery telephone system contain a dry cell battery. The function of the battery is to:

a. activate the ringing mechanism.

b. energize the antisidetone circuit.

c. provide current to the transmitter.

d. supply a bias voltage to the receiver.

5. Assume that you are going to use the handset shown in figure 30 of the local-battery telephone system. The purpose of locating the handset switch at this convenient point is to enable the user to operate the switch while:

a. listening.

b. signaling.

c. monitoring.

d. transmitting.

6. The transmitter and receiver of most telephone sets are mounted in the handset. This arrangement intends to increase the output of the transmitter because:

a. the position of the receiver gives the transmitter a booster effect.

b. it assures the proper positioning of the transmitter while the user is speaking.

c. the user will speak louder when the receiver blocks room noise from one ear.

d. transmitters used in handsets are designed to be more efficient than those mounted in the telephone case.

7. What are the advantages of using the common-battery system as compared with the local-battery system?

a. The storage battery gives the voice signals uniform amplitude, is more economical to maintain, allows the operator to handle more lines and has a less complex system.

b. An automatic signaling system has a greater amplitude in the voice signal, allows the operator to handle more lines, and allows electrically unbalanced transmission lines.

c. An automatic signaling system has greater amplitude in the voice signal, allows the operator to handle more lines, and is a less complex system.

d. The storage battery gives the voice signal a uniform amplitude, is more economical to maintain, allows operator to handle more lines, and is an automatic signaling system.

8. Both local-battery and common-battery systems are used in military applications. The local-battery systems are desirable for tactical communications because of the:

a. economical use of dry cell batteries.

b. automatic supervision to the operator.

c. uniform amplitude of the voice signals.

d. quality of transmission over field wire circuits.

9. A telephone system that provides telephone communications within a particular local area, such as an Army post, maneuver area, town, or village is considered to be:

a. Central Office.

b. telephone exchange.

c. telephone station.

d. telephone switchboard.

10. A device in a telephone set that serves the purpose of separating the transmitting circuit from the receiving circuit is called a:

a. transformer.

b. secondary circuit.

c. induction coil.

d. handset switch.

11. What two essential components are found in a local-battery phone that are not found in a common-battery phone?

a. Ringer, battery.

b. Ringer, hand generator.

c. Hand generator, capacitor.

d. Battery, hand generator.

12. How is the switchboard signaled in a common-battery system?

a. By cranking hand generator.

b. By lifting receiver.

c. By pressing ring switch.

d. By closing open to talk switch.

13. An induction coil could be described as:

a. consisting of two coils, a transformer coil and a secondary coil with a common connection.

b. consisting of two coils, a transformer coil and a primary wound on a single iron core.

c. consisting of one coil that does not pass direct current into the transmitting circuit wound on an iron core.

d. consisting of two coils a secondary and a primary with a common connection.

14. The primary difference between a common-battery switchboard and a local-battery switchboard is the:

a. trunk circuit.

b. ringing machine.

c. battery supply.

d. operator procedure.

15. A switchboard cord contains three conductors and three contacts. These three elements are referred to as:

a. tip, ring, and sleeve.

b. positive, negative, and busy.

c. tip, ring, and ground.

d. positive, negative, and ring.

16. In a common-battery system there are two important paths. They are:

a. direct current path and a talking path.

b. a talking path and a ringing path.

c. direct current path and an automatic signaling path.

d. a talking path and a filter path.

17. Two important advantages of a common-battery system over a local battery system are:

    a. more answering positions and faster answering.

    b. automatic signaling and faster answering.

    c. provisions for supervision and three conductor cords.

    d. automatic signaling and provision for supervision.

18. Line signaling on a common-battery switchboard is usually accomplished with:

    a. auxiliary contacts.

    b. lamps.

    c. shutters.

    d. push to talk switch.

19. When a telephone line terminates in a switchboard this terminal point is called a:

    a. plug.

    b. jack.

    c. relay.

    d. spade plug.

20. There are two types of line jacks used. They are called:

    a. simple jacks and cut-off jacks.

    b. cut-off jacks and open jacks.

    c. auxiliary jacks and cut-off jacks.

    d. simple jacks and ring down jacks.

CHECK YOUR ANSWERS AGAINST LESSON 2 SOLUTION SHEET (PAGE 192) AND MAKE NECESSARY CORRECTIONS.

LESSON 3

WIRE TRANSMISSION PRINCIPLES

OBJECTIVE:

Action:	You will be able to describe the characteristics of telephone transmission lines, describe construction principles and types of circuits employed with transmission lines.
Conditions:	You will be provided the lesson material and a lesson exercise sheet.
Standard:	You must respond correctly to a least 17 of the 20 questions in the lesson exercise.

CREDIT HOURS:	1
TEXT ASSIGNMENT:	Read inclosed text
MATERIALS REQUIRED:	Pencil or pen
SUGGESTIONS:	None

CHAPTER 6

TRANSMISSION LINES

56. Introduction.

The preceding chapters have discussed all the basic elements of the local- and common-battery telephone systems except one--the transmission line. Telephone sets, switchboards, and their components were explained in detail, but the transmission line was considered only as a metallic conductor for signals traveling between the individual telephone sets and the interconnecting switchboard. The transmission line is a major element in all telephone systems, however, for it presents problems which vitally affect practical operation. Chief among these problems are the power losses along the lines, and the distortion and interference which result from interaction between adjacent lines. This chapter explains these problems and their solutions.

57. Types of Transmission Lines.

Before considering the electrical characteristics of transmission lines, this paragraph describes the physical characteristics of some of the types of lines in common use. Three main classes of transmission lines are used in military telephone installations: open-wire lines, cables, and field wires.

a. Open-wire lines.

(1) Open-wire lines are parallel bare conductors strung on electrical insulators, mounted on the cross arms of telephone poles, as shown in figure 50. The wires may be made of hard-drawn copper, steel, copper-galvanized steel, or iron. Two wires constitute a line. The two wires of a line are spaced a standard distance apart, usually

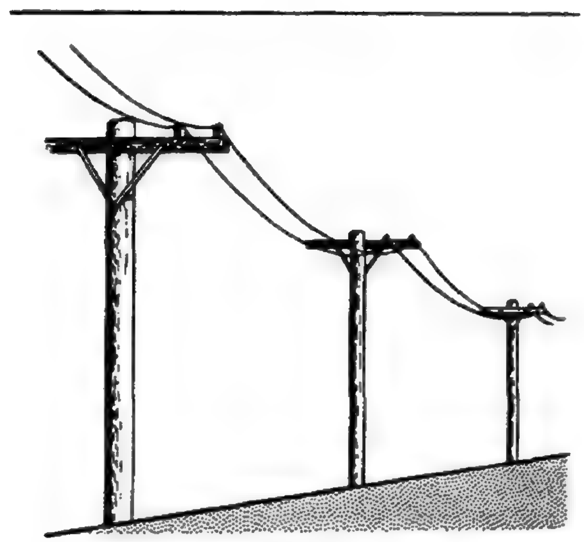


FIGURE 50. Open-Wire Line.

8 inches. When more than one pair of wires are strung on the same poles, the spacing between wires usually is 10 or 12 inches, depending on the type of cross arms in use.

(2) The wire diameters most frequently used for open wire lines range from 80 mils to 165 mils (1 mil is equivalent to 1/1,000 inch).

b. Cables. Cables may be described as consisting of one or more pairs of wires, each wire individually insulated; the wires of a pair are twisted together, the pairs usually are twisted together, and the entire group is covered with an outer covering. Two types of cable frequently used military installations are illustrated in figure 51.

(1) Spiral-four cable contains four conductors, in two pairs (fig. 51). Each conductor is made up of seven strands of copper, and is covered with a polyethylene insulation. The insulation on one pair of conductors is light colored, and that on the other pair is dark, to facilitate identification of circuits. The insulated conductors are spiraled around a polyethylene core. A polyethylene belt surrounds the spiraled conductors, and is in turn surrounded by black carbon tape. Around the tape is a stainless-steel braid, to provide mechanical strength for the cable. This is covered by an outer jacket of vinyl.

(2) Five-pair rubber cable contains ten conductors, arranged in five pairs, as shown.

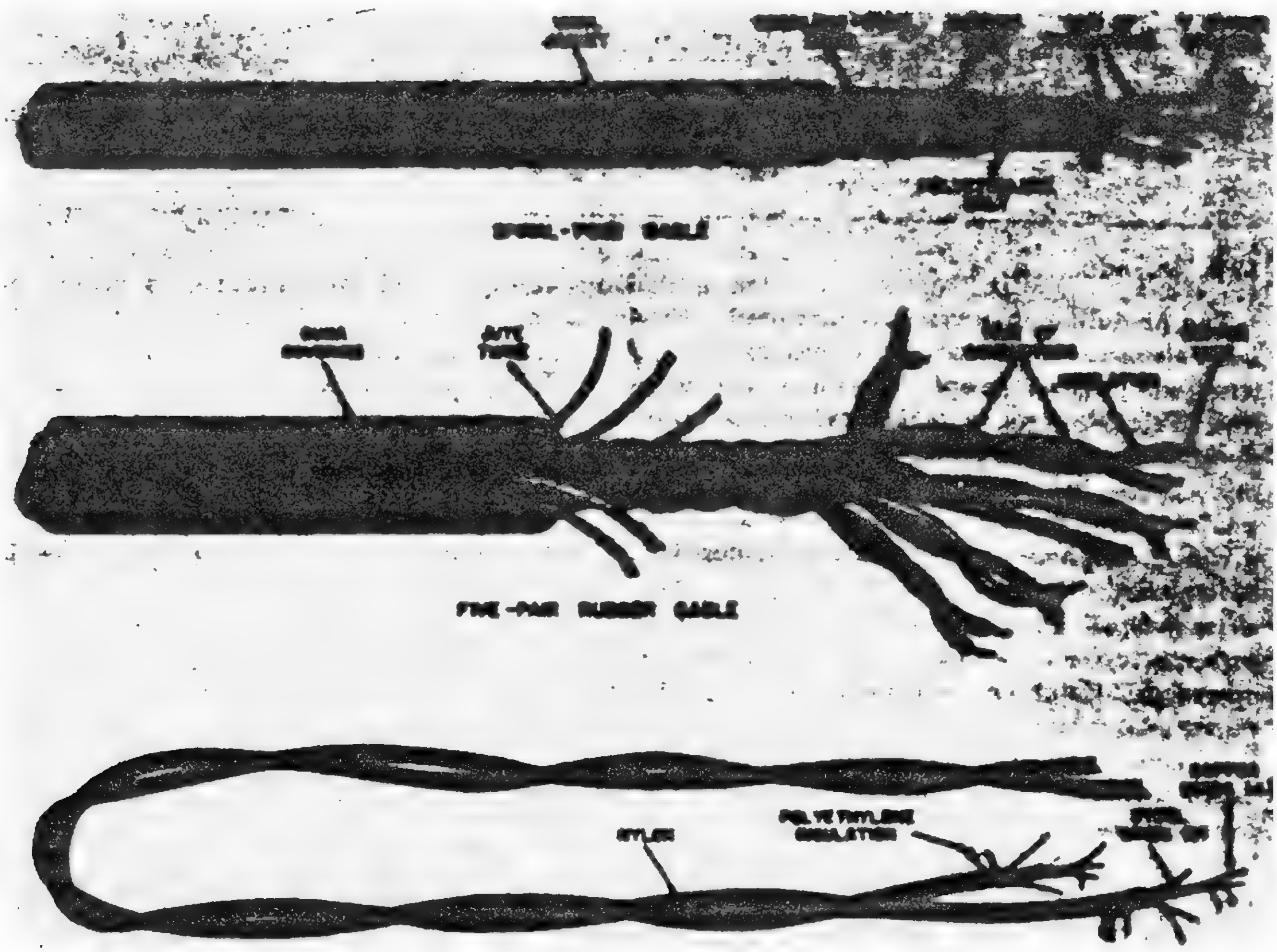


FIGURE 51. Types of Cables.

Each conductor is a tinned solid-copper wire, covered with rubber or latex insulation. The insulation on one wire of each pair is white and the insulation on the other wires is colored-coded for identification, a different color insulation being used for each wire--red, yellow, green, blue, and black. The outer covering is made of buna (a synthetic rubber), which encloses, in addition to the ten conductors, five strands of jute twine, inserted as filler and for mechanical strength.

(3) Toll cable (not illustrated) differs from the two types just described primarily in that its outermost covering is made of lead. In general, it is used in permanent installations for long-distance transmission, and either may be strung overhead on poles, or installed underground. The conductors usually are twisted pairs of annealed copper wire, insulated either by spirally wound paper tape or by a covering formed on the wires from paper pulp. The wire sizes customarily used are #19 and #16 AWG, although smaller wires sometimes are used for short distances.

c. Field-wire lines. Field wires consist of simple pairs of insulated wire twisted together. Field-wire lines are used in military applications for emergency and temporary installations. They are used primarily for short lines, because of their high transmission loss. The military designations for the field wires most commonly used are W-110-B, WD-14/TT, and WD-1/TT (the latter type illustrated in fig. 51). Each of the two conductors has seven strands, of which four are copper and three are steel. Each seven strand conductor is covered with polyethylene insulation and an outer protective covering of nylon.

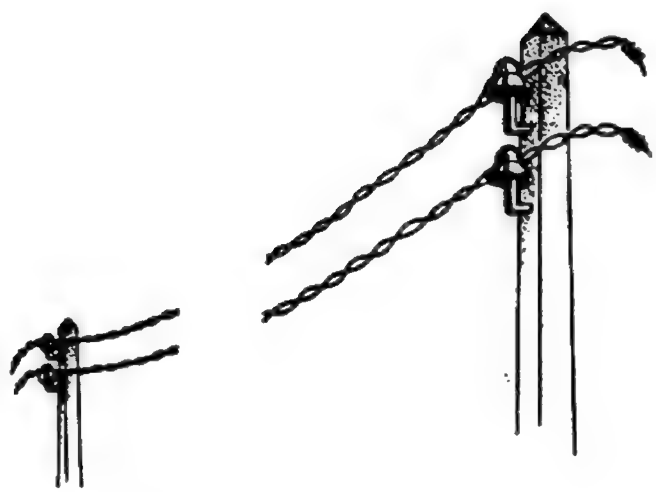


FIGURE 52. Arrangement of Twin Pair

d. Talking range of lines. Although field wires as a rule are used as single pairs, two pairs occasionally are used in order to extend the talking range (fig. 52). The two wires of one pair are connected to form one conductor of the line, and the two wires of the other pair are connected to form the other conductor of the line. In

this way, the resistance of the line is cut in half, thus extending its useful range. The talking ranges under various operating conditions of a single pair and of a twin pair (of wires) are shown in Table #1 below. The range for wire laid on the ground is lower than the range for the same wire strung above the ground. Wetness (rain or, sometimes, heavy dew) greatly reduces the range of all the wires when they are used without insulators.

Wire	Single pair (in miles)		Twin pair (in miles)					
	Conditions		Strung on poles with insulators (8-inch spacing)		Strung on trees without insulators (8- to 24-inch spacing)		Laid on ground (8- to 24-inch spacing)	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
W-110-B	11	18	65	65	25	65	15	65
WD-14/TT	12	20	70	70	27	70	17	70
WD-1/TT	12	20	70	70	27	70	17	70

TABLE #1

58. Characteristics of Transmission Line.

a. Electrical length of line. An important characteristic of a transmission line, significant in determining its behavior, is its electrical length. The electrical length expresses the relationship between the length of a line and the wavelength of the signal being transmitted over the line. The wavelength of an electrical wave is defined as the velocity with which the wave is traveling along the conductor divided by the frequency of the signal, or

$$\text{wavelength} = \frac{\text{velocity}}{\text{frequency}}$$

The velocity of propagation at 1,000 cycles per second on open-wire lines varies from 176,000 to 180,000 miles per second, approximately; on nonloaded toll cables, it varies from 47,600 to 65,300 miles per second, approximately, for the sizes customarily used.

(1) Short lines. A short line may be defined as one in which the length of the line is considerably shorter than the wavelength of the transmitted signal. A, figure 53A, represents a line that is electrically short. This line is 1 loop mile in length. The signal applied to the sending end of the line has a frequency of 1,000 hertz; therefore, if the velocity is assumed to be 180,00 miles per second, the wavelength of the signal is 180 miles, or the 1-mile line is 1/180 of a wavelength electrically. A line 1 mile long having

velocity of propagation of 60,000 miles per second is 1/60 of a wavelength electrically. Although both lines, or pairs, are 1 mile in physical length, the slower circuit is electrically three times as long as the faster circuit. Note that electrical length as defined here is based on phase change per unit length, in contrast to electrical length based on attenuation per unit length.

(2) Long lines. A long line may be defined as one in which the length of the line is approximately equal to, or longer than, the wavelength of the transmitted signal. B, figure 53A, represents a line that is electrically long, for the line is 360 miles in length and it carries a 1,000 hertz signal having a wavelength of 180 miles. As the wave travels along this line, two complete voltage and current waves exist on it at any single instant of time. Under different circumstances, the same line may behave either as an electrically short or an electrically long line. For example, if the line shown in A, figure 53A, is energized by a signal having a frequency of 200,000 hertz, corresponding to a wavelength of .9 mile, it is

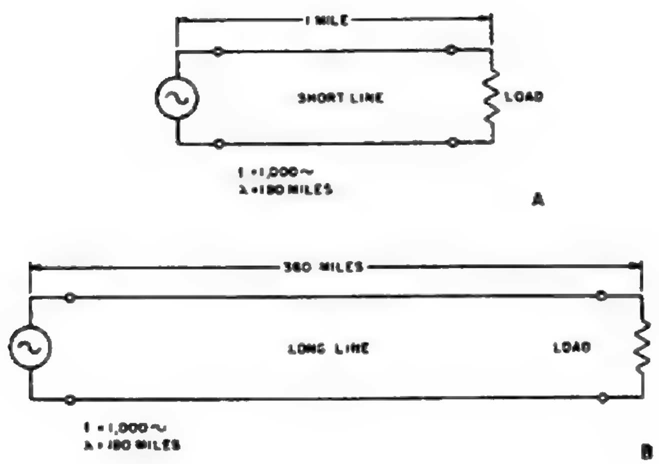


FIGURE 53A. Short and Long Line.

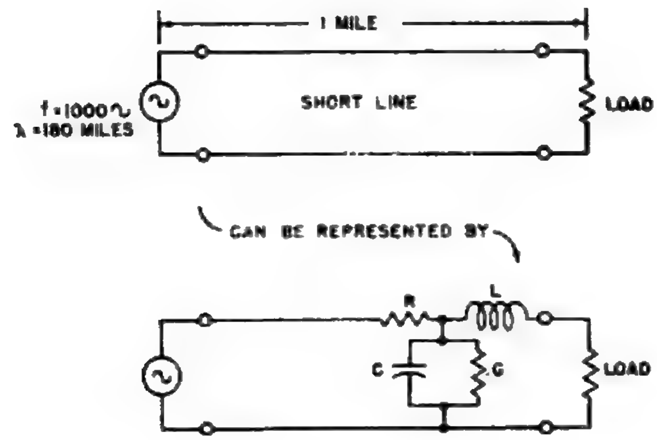


FIGURE 53B. Short Line and Its Equivalent Circuit (Lumped)

considered (and behaves like) a long line; or, if the line shown in B is energized by a signal having a frequency of 60 hertz, corresponding to a wavelength of 3,000 miles, it is considered (and behaves like) a short line.

b. Line parameters. Transmission lines, because of their basic structure, possess certain line parameters. These parameters, commonly called constants, comprise series resistance, R, series inductance, L, shunt capacitance, C, and shunt-leakage conductance, G--all these with respect to

a unit length, usually a mile. The numerical values of these constants not only depend on the size of the conductors, their spacing, and insulation, but also vary with the frequency of the transmitted signal and the weather conditions.

(1) Constants. The four line parameters mentioned above are distributed along the entire length of the line and for this reason are called distributed constants. If the parameters had been concentrated in one place, for example, the way a resistor concentrates resistance, they would have been called lumped constants. In the study of transmission lines, a transmission line is shown in the form of an equivalent circuit in which the distributed constants for a given length are shown in the form of lumped constants (fig. 53). The series resistance, R, series inductance, L, shunt capacitance, C, and shunt conductance, G, for a unit length of 1 mile, are shown as lumped constants.

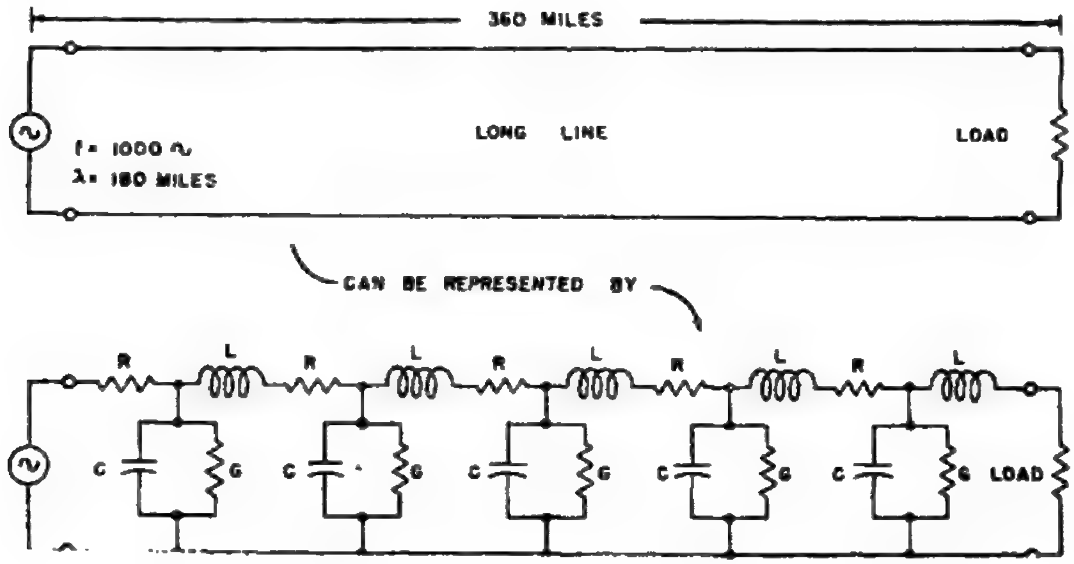


FIGURE 54. Long Line and Its Equivalent Circuit (Distributed Constants).

A long transmission line can be considered to be made up of a series of unit sections (fig. 54). In this case, five sections are used to represent the 360-mile line so that each section represents a 72-mile length of the line. Any convenient length can be used as the unit length, but 1 mile is the preferred length. By using this method to represent transmission lines, the study of their behavior is simplified greatly.

TABLE #2

Type of line	Size of wire and spacing	Distributed constants per loop mile			
		R (ohms)	L (henrys)	C (micro-farads)	G (mi-crohms)
Open-wire	104 mils = 8 inches.	10.36	.00340	.00905	.29
	128 mils = 8 inches.	6.87	.00327	.00944	.29
	165 mils = 8 inches.	4.19	.00310	.00996	.29
Nonloaded cable.	#19 AWG	86.0	.001	.062	1.4
	#16 AWG	42.0	.001	.062	1.4

(2) Values for distributed constants. Values for distributed constants of commonly open-wire lines and nonloaded cables are given in Table #2 below. Note that as the wire diameter of an open-wire line increases the series resistance decreases appreciably and the series inductance decreases only slightly. The shunt capacitance increases slightly and the shunt conductance does not change. This is because the shunt conductance is actually leakage conductance and depends only on the nature of the insulating material separating the wires. In the case of cables, only the series resistance decreases as the wire size increases (lower gage number), the other constants remaining essentially constant.

59. Characteristic Impedance.

The characteristic impedance, Z_O, of a network is the value of load impedance which makes the impedance at the input terminals of the network equal to the load impedance. The tee and pi sections of figure 55 help to explain this. For example, in the tee section of A, the load impedance, Z_R, is 600 ohms. This resistor is in series with the right-hand

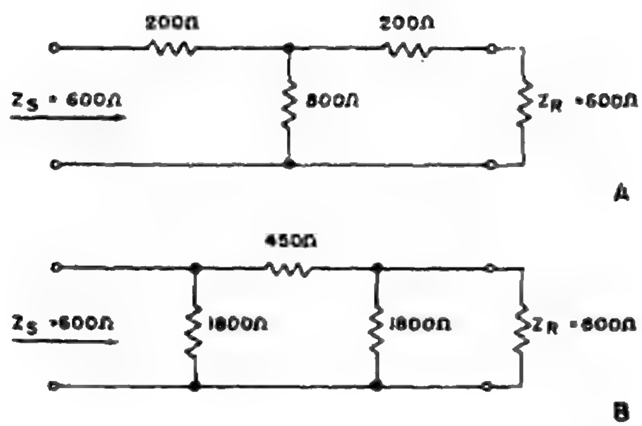


FIGURE 55. Tee and pi Sections Terminated in Zo.

200-ohm resistor of the section, making a combined resistance of 800 ohms. Combining this resistance with the 800-ohm shunt resistor of the section gives 400 ohms. Finally, by adding the left-hand 200-ohms resistor to 400 ohms, the input resistance, Z_S, is found to be 600 ohms. Since this is the same value as the terminating or load resistance, the characteristic impedance of this tee section is said to be 600 ohms. A similar calculation can be made for the pi section shown in B, the characteristic impedance of which is also 600 ohms. Since a change in the values of the elements of the network changes its characteristic impedance, the characteristic impedance of a network is a property which depends on the elements or constants of the network.

a. Long Lines. The characteristic impedance of a long line is determined by its distributed constants. Depending on the type of line, the characteristic impedance may be nearly a pure resistance, as in the case of low-loss open-wire lines, or may consist of both resistance and capacitive reactance, as in the case of cables. For example, the characteristic impedance of a 165-mil, two-wire, open-wire line at a frequency of 1,000 hertz comprises a resistance of 562 ohms and a capacitive reactance of 58 ohms. Note that the resistance is nearly 10 times the capacitive reactance. On the other hand, the characteristic impedance of a 19-gage cable at the same frequency comprises a resistance of 340 ohms and a capacitive reactance of 314 ohms. It is this quality of cable that accounts for the low wave-propagation velocity of signals transmitted over them.

b. Characteristic impedance. Figure 56 aids in understanding the development of the characteristic impedance of a long line. In order to simplify the calculations, the basic section of the line is represented as a tee section containing only resistance. If the single section shown in A is open-circuited, the sending end, or input impedance, E_S, is 200 ohms in series with 800 ohms, or 1,000 ohms. If a second section now is connected to the input terminals of the first section, as in B, the right-hand 200-ohm resistance of this second section adds to the 1,000-ohm input resistance of the first section, giving a combined resistance of 1,200 ohms. This is combined in parallel with the shunt resistance of 800 ohms, making the equivalent resistance 480 ohms. Finally, adding this in series with the left-hand 200-ohm resistance, the input resistance for the two sections is found to be 680 ohms. Using a similar sequence of calculations, the input impedance for three sections can be shown to be 620 ohms, as in C. As more sections are added, the input impedance decreases slowly, approaching a steady value of 600 ohms in D. This value is the characteristic impedance of the long line.

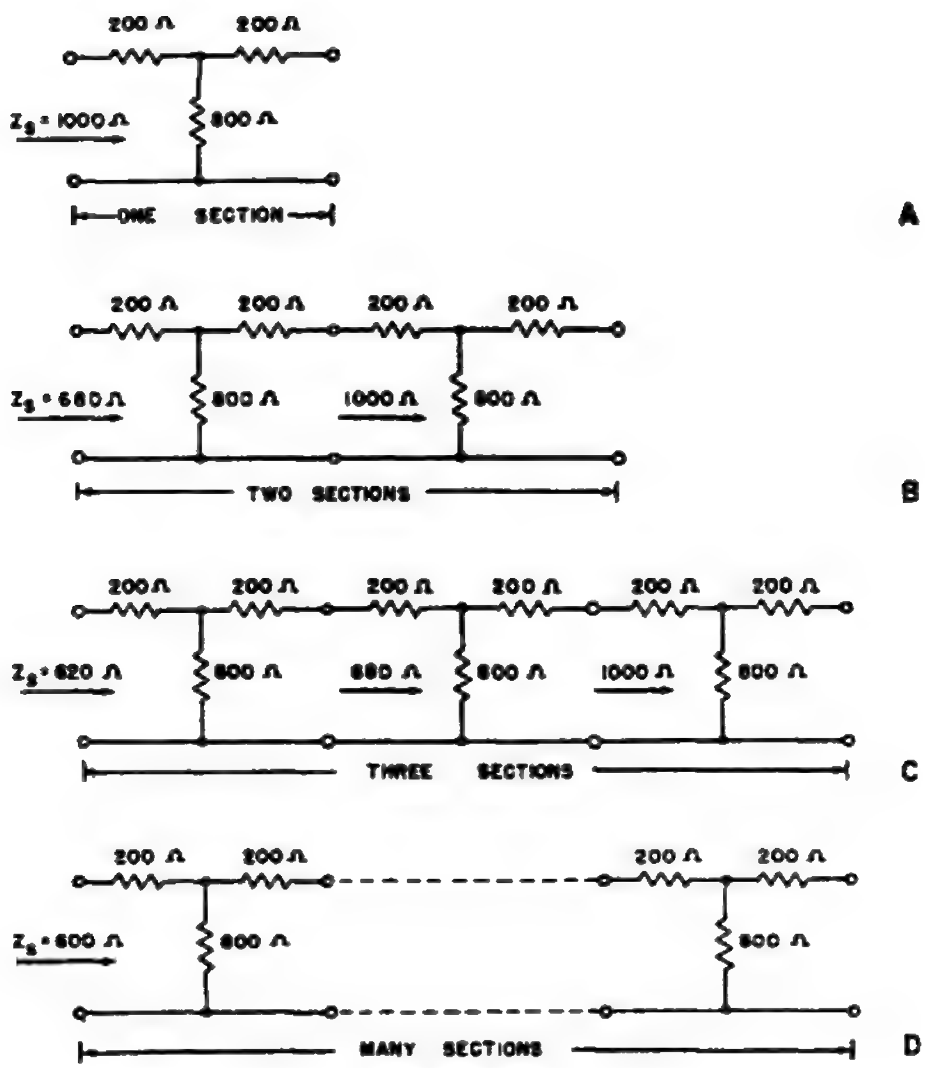


FIGURE 56. Characteristic Impedance of Long Line.

c. Impedance measurements. The characteristic impedance of an open-wire line or cable can be determined by making two impedance measurements. First, the impedance at the sending (near) end is measured with the receiving (distant) end open-circuited. This gives the open-circuit impedance, Z_{OC}. Then the impedance at the sending end is measured with the distant end short-circuited. This gives the short-circuited impedance, Z_{SC}. The characteristic impedance can be calculated from these two measured impedances by using the following formula:

$$Z_O = Z_{OC}Z_{SC}$$

In A, Z_{OC} for the single section is 1,000 ohms, and Z_{SC} is 200 ohms and 800 ohms in parallel, or 360 ohms. Substituting these two values in the formula, Z_O is found to be 1,000 times 360, or 600 ohms. In other words, for a uniform line, the characteristic impedance of the entire line is the same as that of a single section of the line.

60. <u>Transfer of Power to Transmission Line</u>.

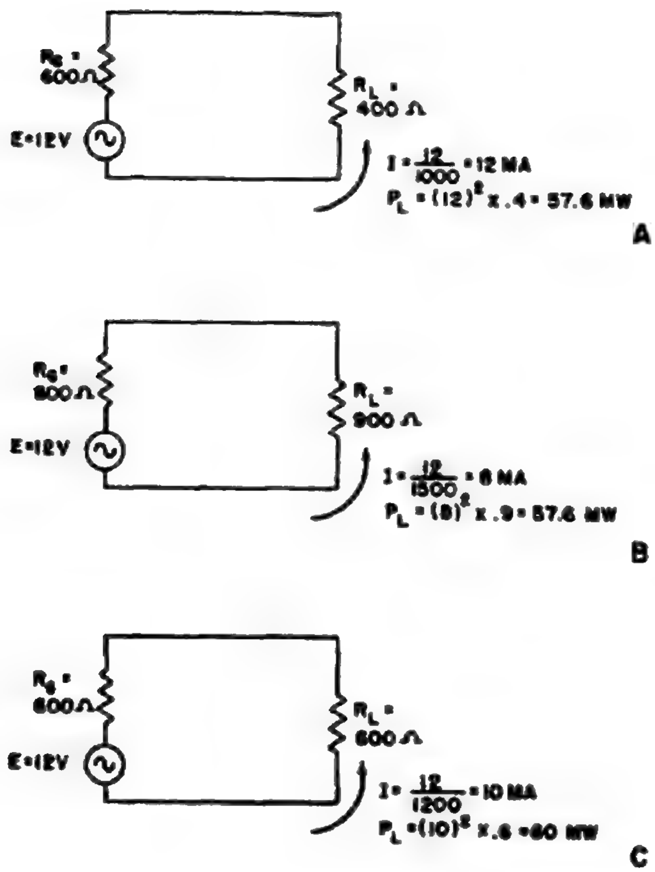


FIGURE 57. Power Transfer to Variable Load.

Since a transmission line may cause considerable power loss, it is important in telephone communications that lines be designed in such a way that maximum power is transferred from the transmitter to the receiver.

a. Maximum power transfer.

(1) The condition for maximum power transfer from a source to a load can be developed with the aid of figure 57. In A, a 12-volt generator with an internal resistance, R_G, of 600 ohms is connected to a load resistance, R_L, of 400 ohms.

Applying Ohm's law, current I is 12/1,000 ampere, or 12 ma. The power delivered to the load is found by using the formula: $P=I^2RL$, where I is in milliamperes, RL is in kilohms, and P is in millowatts. The power delivered to the 400-ohm (.4 kilohm) load is 57.6 mw.

(2) B shows the same circuit with the load resistance changed to 900 ohms. The current is now 12/1,500 ampere, or 8 ma. The power delivered to the load is therefore $(8)^2$ times .9, or 57.6 mw. Note that this is the same load power as that produced for the conditions given in A.

(3) In C, the load is changed to 600 ohms, the same value as R_G. The current becomes 12/1,200 ampere, or 10 ma, and the load power is now (10) times .6, or 60 mw. This is larger than the load power obtained under the conditions shown in A and B.

(4) If the load resistance is changed to values above and below 600 ohms, the corresponding values of power delivered to the load can be calculated by the method used in the previous examples. The results of such calculations are shown in the table below. From the data, a power transfer curve, such as that shown in figure 58, may be plotted. It can be seen from the tabulation of load power versus load resistance that maximum power is transferred from a generator to a load when the resistance of the load equals the internal resistance of the generator. This relationship is called the maximum power transfer theorem for resistive networks.

Load resistance R_L (kilohms)	Load current (ma)	Load power (mw)
0.0	20.0	0.0
.1	17.14	29.5
.2	15.0	45.0
.3	13.33	53.5
.4	12.0	57.6
.5	10.9	59.5
.6	10.0	60.0 (max)
.7	9.25	59.8
.8	8.6	59.0
.9	8.0	57.6
1.0	7.5	56.2
1.1	7.08	55.0
1.2	6.67	53.3
1.3	6.32	52.0
1.4	6.00	50.4
1.5	5.71	48.9
1.6	5.45	47.7

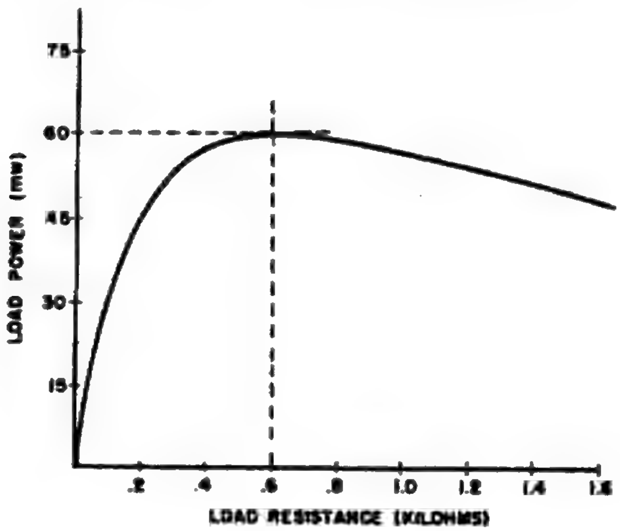


FIGURE 58. Variation of Power Transfer

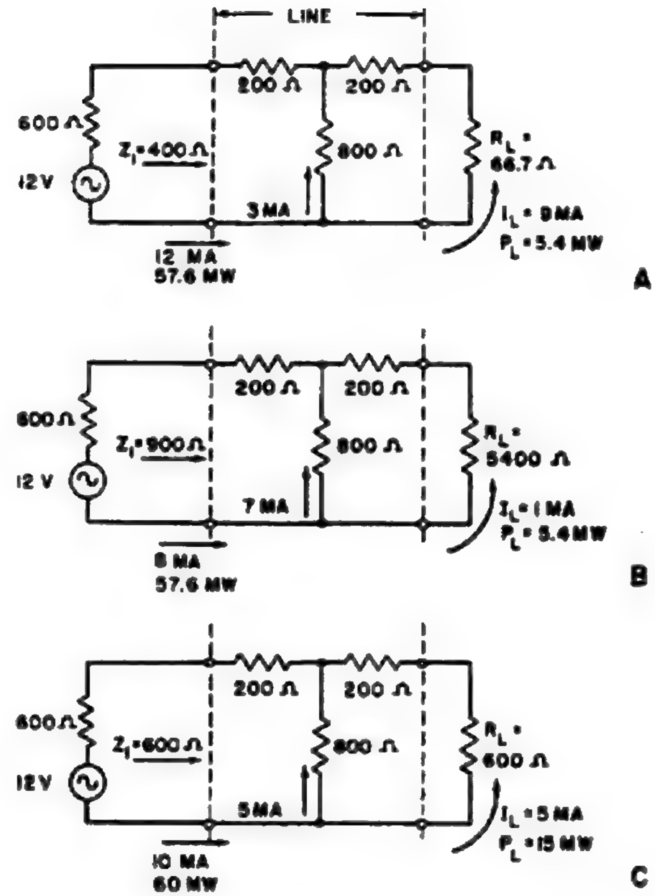


FIGURE 59. Power Transfer from Transmission Line to Load.

b. Application of maximum power transfer theorem to transmission line. Figure 59 illustrates the application of the maximum power transfer theorem to transmission lines. For simplicity, the transmission line under consideration is assumed to be replaced by a tee section composed of pure resistances. The characteristic impedance of such a section has been shown to be a pure resistance of 600 ohms (fig. 55).

(1) In A, figure 59, the line is shown to be terminated in a resistance of 66.7 ohms. By using the methods previously discussed for combining series-parallel resistances at the input terminals of the line, Z_I, is found to be 400 ohms. From the table in a(4) above, the current and power in a 400-ohm resistance connected to a 12-volt generator in series with an internal resistance of 600 ohms are 12 ma and 57.6 mw, respectively. However, these are values for current and power at the input terminals of the circuit. By applying the laws of division of current in parallel circuits, the line current of 12 ma divides so that 3 ma flow through the shunt 800-ohm resistance of the tee section, and 9 ma flow through the actual load of 66.7 ohms. The power delivered to this load is therefore 5.4 mw.

(2) In B, the load resistance is changed to 5,400 ohms. This value makes the resistance at the input terminals of the line 900 ohms. Therefore, the line current is 8 ma, and the power delivered to the input terminals of the line is 57.6 mw. Again, applying the laws of division of current in parallel circuits, the current through the shunt 800-ohms resistance is found to be 7 ma, so that the load current is 1 ma. The load power again is shown to be 5.4 mw.

(3) Finally, in C, the line is terminated in 600 ohms, the characteristic resistance of the line. Therefore, the input resistance of the line is 600 ohms (by the definition of characteristic resistance). Referring to C, figure 59, the line current and the power delivered to the input terminals of the line are now 10 ma and 60 mw, respectively. Since the two parallel branches are equal in resistance (800 ohms), the load current is one-half of the line current, or 5 ma. This makes the load power $(5)^2$ times .6, or 15 mw. This is only one-fourth of the input power because of the attenuation of the line, but it is considerably greater than the load power obtained for the values of load impedance shown in A and B.

(4) The power delivered to a load resistance varied on either side of 600 ohms in such a circuit is tabulated in Table #3 at left of page. The tabulation shows that maximum power is transferred to the load by the transmission line when the line is terminated in its characteristic resistance (600 ohms, in this example). Note that, although the input power varies only slightly when the termination is not Z_O, the load power varies considerably from its maximum value.

R_L (kilohms)	Input resistance (kilohms)	Line current (ma)	Load current (ma)	Input power (mw)	Load power (mw)	Line loss (mw)
0.0	0.36	12.5	10.0	56.1	0.0	56.1
.0667	.4	12.0	9.0	57.6	5.4	52.2
.28	.5	10.9	6.81	59.5	13.0	46.5
.6	.6	10.0	5.0	60.0	15.0 (max)	45.0 (min)
1.133	.7	9.25	3.47	59.8	13.65	46.15
2.2	.8	8.6	2.15	59.0	10.2	48.8
5.4	.9	8.0	1.0	57.6	5.4	52.2
	[1] 1.0	7.5	.0	56.2	.0	56.2

[1] Open circuit.

TABLE #3.

In order to reduce the line loss to a minimum, therefore, the line must be terminated in its characteristic impedance.

61. Attenuation.

Attenuation is the term used to express the loss of power that occurs in a network or transmission line. This loss is attributable to the line parameters, especially the series resistance and shunt conductance. These constants, whether distributed or lumped, dissipate power in the line and therefore cause the output power of the line to be less than its input power. This is illustrated in figure 59, and in the table (par. 60b(4)). For example, in C, the power delivered to the line is 60 mw, whereas the load power is only 15 mw. The difference in power, 45 mw, is dissipated in the three resistances of the tee section. By noting the currents in these resistances, it will be seen that the left-hand 200-ohm resistance dissipates $(10)^2$ times .2, or 20 mw; the right-hand 200-ohm resistance dissipates $(5)^2$ times .2, or 5 mw; and the shunt 800-ohm resistance dissipates $(5)^2$ times .8, or 20 mw. Thus, the total dissipation is 45 mw.

a. Decibel. Ordinarily, the attenuation of a line is expressed as a ratio of input to output power. To simplify such calculations, the dB (decibel) has been adopted as a measure of attenuation. A decibel is defined as the attenuation which occurs on a line when the ratio of input to output power is 1.25. The total attenuation in decibels of a transmission line can be calculated by using the following formula:

$$\text{Attenuation in dB} = 10 \log. \frac{\text{input power}}{\text{output power}}.$$

In C, figure 59, the ratio of input to output power is 60/15, or 4. The attenuation in dB therefore is 10 log 4, or 6 dB. Similarly, in A and B, the power ratio is 57.6/5.4, or 10.67; the attenuation is therefore 10 log 10.67, or 10.28 dB.

b. DB table. In order to facilitate calculation of line loss, the attenuations in dB and the power ratios to which they correspond are tabulated in the table below. When the power ratio is an exact power of 10, such as 100 or 1,000, the attenuation is 10 times the number of zeros in the ratio. For example, when the ratio is 100 (two zeros), the attenuation is 10 times 2, or 20 dB. Similarly, when the ratio is 10,000 (four zeros) the attenuation is 10 times 4, or 40 dB. The attenuation corresponding to a power ratio which is found to be a multiple of a power of 10, such as 5,000, can be found by adding the attenuations corresponding to the multiple to the power of 10. For example, when the power ratio is 5,000, the attenuation is found to be 7 (corresponding to the multiple 5 in the table) plus 30 (corresponding to 1,000), or 37 dB. By using this method, the reader can verify the fact that the attenuation corresponding to a power ration of 200 is 23 dB, and that the attenuation corresponding to a power ratio of 400 is 26 dB. When the value of the power ratio is doubled, the attenuation is increased by 3 dB, so that if the ratio is 800, or twice 400, the attenuation is 3 dB higher than 26 dB, or 29 dB. These fundamental relations are useful in determining the attenuations of lines and networks.

Power ratio	Attenuation (dB)
1	0
1.25	1
2	3
4	6
5	7
10	10
100	20
1,000	30
10,000	40

c. Factors influencing attenuation. The attenuation of a pair usually is expressed in dB per loop mile of line. One loop mile is 1 mile of two-wire line--that is, 2 miles of wire. The attenuation per loop mile of an open-wire pair depends on the size, spacing, and material of the conductors, and on the kind and number of insulators and their condition (wet or dry). Ice has a large effect on attenuation, particularly at high frequencies. The frequency of the current has an important effect on attenuation. Under average conditions, an open-wire pair has less attenuation per mile than either cable or field wires. For example, the dry weather attenuation at 1,000 hertz for 8-inch spaced wires of 165-mil, 128-mil, and 104-mil copper is, respectively, .032, .049, and .070 dB per loop mile at 68° F. An approximate expression for this attenuation is as follows:

$$\text{Attenuation} = \frac{R}{2}\ \frac{C}{L} + \frac{G}{2}\ \frac{L}{C} \times 8.686 \text{ dB per loop mile}$$

62. Loading of Transmission Line.

Loading, as applied to a transmission line, is the method of increasing the series inductance of a line by the addition of external inductance. Its purpose is to improve the performance of the line by reducing attenuation and distortion. Loading may be either: lumped loading or continuous loading.

a. Lumped loading is effected by the addition of loading coils (which have relatively high inductance) at regular intervals along the line. The loading coils used at present consist of two windings on a molybdenum permalloy dust core (C, fig. 60). With this core material, high inductance is obtained with a rather small coil. Before the molybdenum permalloy dust core was perfected, loading coils had iron dust or permalloy dust cores illustrated in A and B. For the same inductance value, these coils are physically larger.

b. The insertion of heavy loading coils in submarine telephone and telegraph cables would subject them to excessive strain at the points of insertion. For this reason, a different method of increasing series inductance, called continuous loading, is used. Continuous loading is effected by wrapping the cable conductor with a tape or wire of magnetic material, such as iron or permalloy. Because such loading distributes the inductance continuously along the line, it causes the line to behave like one with distributed constants.

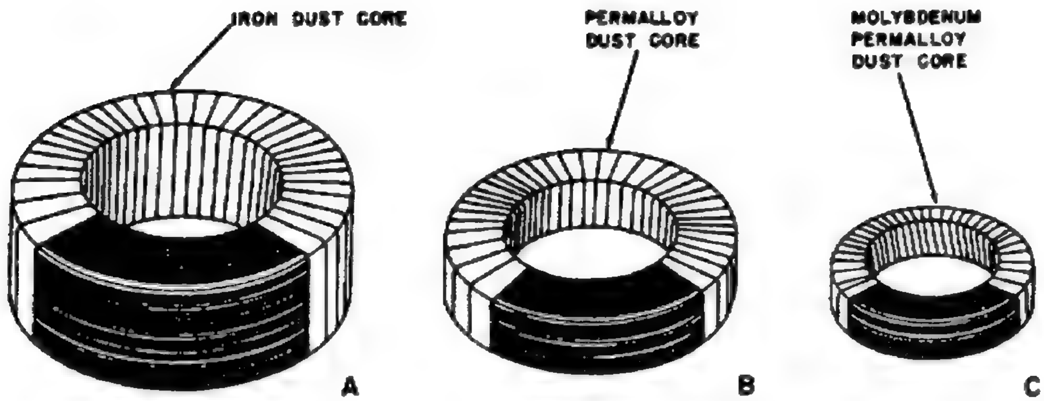


FIGURE 60. Core Materials of Loading Coil.

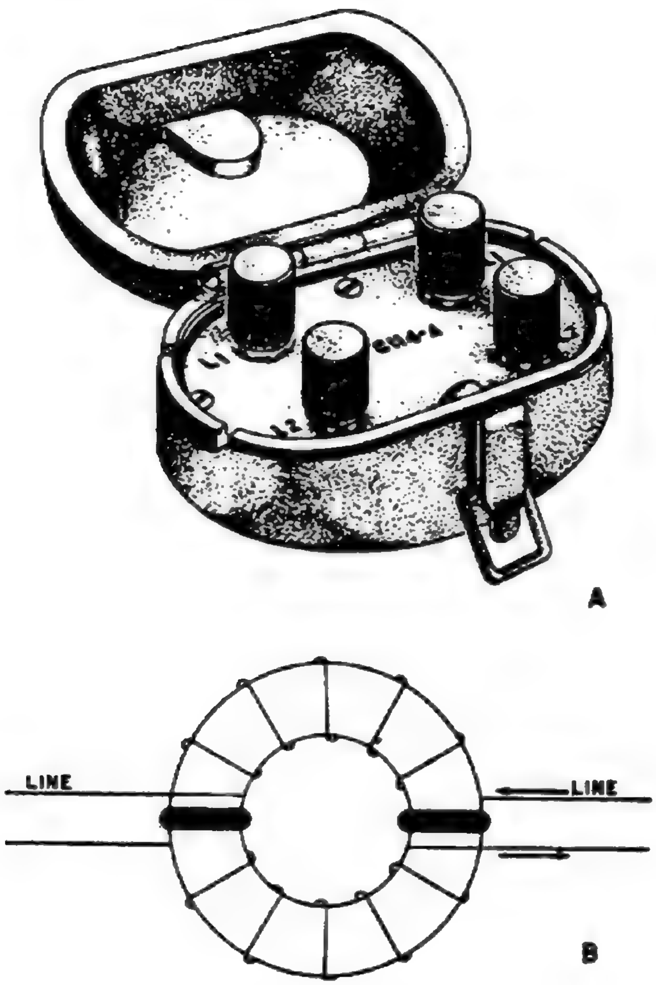


FIGURE 61. Typical Loading Coil and Symbol.

c. Commercially, at the present time, only land cables are loaded in the United States. For open-wire lines, excessive distortion is overcome by the use of compensating or corrective networks, and excessive line losses are compensated for by means of repeaters or amplifiers. For military purposes, however, both cables and field wire lines are loaded to increase the talking range. Figure 61 shows one of the loading coils used in military applications. This coil has an inductance of 88 millihenrys. It is inserted at approximately 1-mil intervals on field wire. In order for loading to be effective in increasing the talking

range, the insulation between wires, or between wires and ground, must be good, and the loading coils must be installed carefully. For example, when the three field-wire lines listed in the table in paragraph 57d are loaded, as recommended, with loading coil as shown in A, figure 61, the talking ranges of a single pair (wet) are increased from the values given in the table to 19, 22, and 90 miles, respectively. The talking ranges of a single pair (dry) are increased to 35, 40, and 90 miles, respectively. The symbol used schematic diagrams to represent loading coils is shown in B

d. The formula:

$$\text{attenuation} = \frac{R}{2} \quad \frac{C}{L} + \frac{G}{2} \quad \frac{L}{C} \times 8.686 \text{ dB per}$$

loop mile, given in paragraph 61c is useful in showing how loading reduces attenuation. In this expression, the term R/2 C/L often is called the series loss, and the term G/2 L/C is called the shunt loss. On most lines, the series loss is many times larger than the shunt loss. With this fact in mind, the effect on attenuation of increasing the inductance may be examined. Practice confirms that increasing the series inductance decreases the series loss and increases the shunt loss. However, as long as the latter is the much smaller loss, the over-all effect will be a reduction in attenuation. If the shunt loss were not much smaller than the series loss, the inductance could not be increased much before the attenuation would be increased by a further addition of inductance. This brings out the importance of good insulation in loaded lines. Inductive loading in the presence of poor insulation actually may increase the attenuation over its nonloaded value. Loading also gives a more uniform attenuation-versus-frequency characteristic over the useful frequency band and therefore reduces distortion caused by nonuniformity.

63. Interference on Transmission Lines.

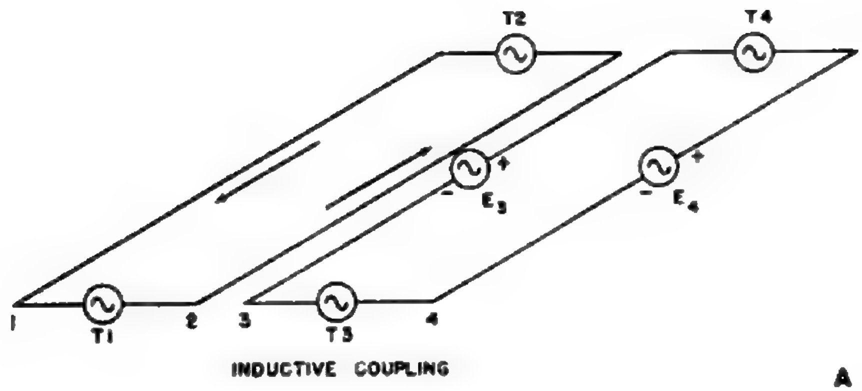
Interference on telephone lines is a serious problem. It may be the result of lightning or other natural disturbances of the atmosphere, or of artificial sources, such as power lines, railway communication facilities, or other communication circuits. Interference from other communication circuits may result when several telephone lines are operating in parallel with each other, and interference from power lines may result when telephone lines are run parallel to power lines for considerable distances.

Such interference--which results from the transfer of electric energy from one telephone line to another, or from a power line to a telephone line--is called inductive interference. Inductive interference may be either crosstalk or noise.

a. Crosstalk. Crosstalk is interference which results when two or more telephone talking circuits exist side by side, and the conversation on one circuit may be heard on the others. Obviously, this is objectionable. It not only may reduce intelligibility, but it may destroy secrecy. Crosstalk can result from any or all of the following causes:

(1) Conduction through leakage paths. Current in one line may be transferred to another line if the insulation between lines is faulty, or if branches of trees or brush come in contact with the wires. This is a problem of proper maintenance, and crosstalk from this cause can be eliminated by keeping the lines in good mechanical condition.

(2) Inductive coupling. One of the basic principles of electricity is that a magnetic field exists around a wire through which current is flowing. The magnetic field consists of concentric circular lines of force at right angles to the wire in space. The strength of the magnetic field varies inversely with the distance from the wire; that is, the greater the distance, the weaker the magnetic field. The magnetic field has the same waveform as the current that produces it. If the current is constant in magnitude and direction, the magnetic field is constant in strength and direction. If the current is alternating, as it is in the case of voice frequencies, the magnetic field varies instantaneously in magnitude, and changes direction every half-cycle. If such a varying magnetic field cuts an adjacent conductor, it induces an alternating emf in the conductor, in accordance with the generator principle. The magnitude of this emf varies inversely with the distance between the center of the magnetic field and the conductor. The conductor is said to be inductively coupled to the original wire which produces the magnetic field. A, figure 62, illustrates how inductive coupling between adjacent telephone circuits can cause crosstalk. Assume that an alternating voice-frequency current is flowing in circuit 1-2, which consists of a telephone line connecting two telephone sets, T1 and T2 (represented by generators). At some instant of time, the current is flowing in the direction indicated by the arrows. A magnetic field exists around both wires, causing the production of a resultant magnetic field. When another telephone circuit, consisting of a line connecting



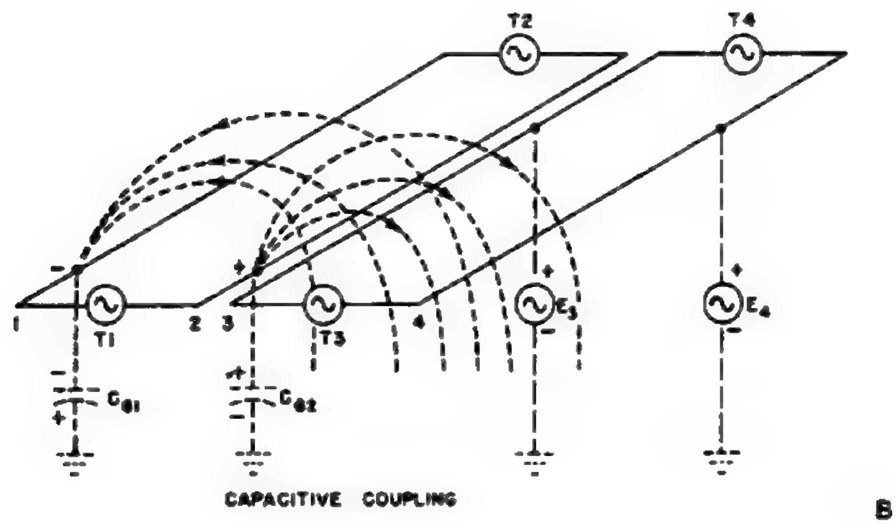


FIGURE 62. Causes of Crosstalk.

telephone sets T3 and T4, is located near the first circuit, as shown, the magnetic field of the first circuit links wires 3 and 4 of the second circuit (field not indicated). Because the magnetic field is varying instantaneously in intensity, an emf is induced in each wire of circuit 3-4. The polarity of the induced emf is the same for both wires. Assume the polarity to be as shown. Wire 3, however, is closer to the center of the magnetic field than wire 4, and, consequently, the emf induced in wire 3 is greater than the emf induced in wire 4. An unbalanced emf (E3-E4) therefore exists in circuit 3-4, and produces a corresponding current through sets T3 and T4. This current, having the same frequency variations as the current in circuit 1-2, causes the conversation in circuit 1-2 to be heard in sets 3 and 4.

(3) Capacitive coupling. Capacitive coupling produces an unbalanced emf in a circuit because of the capacities between the wires of an adjacent circuit and ground and the associated electric fields. This type of coupling between two adjacent telephone lines is illustrated in B, figure 62, which shows a telephone circuit consisting of telephone sets T1 and T2 connected by wires 1-2. The capacitance of these wires to ground are represented by C_{G1} and C_{G2}, respectively. Since the two capacitances are in series between the two wires, a voltage exists across each capacitance. If the capacitances are assumed to be equal, the voltages across them are equal in magnitude but opposite in polarity, as indicated. This causes an electric field to appear between each wire and ground, with the respective directions indicated by the arrows. If a second telephone circuit, consisting of sets T3 and T4 connected by wires 3-4, lies near the first circuit, each of its wires is linked by the field existing at that point. Since the strength of the field diminishes with increasing distance from the source, wire 3 is linked by a stronger electric field than that which links wire 4. This causes wire 3 to be raised to a higher potential above ground than wire 4, so that a difference of potential exists between wires 3 and 4. This potential difference, or unbalanced emf, causes a current having the same frequency variations as the current in circuit 1-2 to flow in circuit 3-4, and produces crosstalk in circuit 3-4. The closer the two circuits are to each other, the greater is their susceptibility to this type of interference.

b. Noise. Interference in telephone lines caused by such sources as adjacent power lines, electric motors and generators, and railway communication facilities, is classified as noise. Electric noise results from the fact that the voltages in electric power lines and electric machines and such sources are not pure 60-cycle sine waves, but also contain many other frequencies. Some

of these frequencies lie in the transmitted voice-frequency range, between 200 and 2,700 hertz. When power lines and telephone circuits exist side by side, voltages at these frequencies may be induced in the telephone lines by exactly the same process discussed in a above. These voltages cause corresponding currents to flow in the lines, and result in the production of noise in the receivers. Noise produced in this manner usually takes the form of a hum of varying pitch. It can be as objectionable and disturbing to the listener as crosstalk.

64. Reduction of Interference on Transmission Lines.

Various methods have been developed to reduce interference on telephone lines.

a. Maintenance of lines. One obvious way of minimizing interference is by keeping telephone lines in good repair. This requires periodic inspection of splices and joints, as well as insulators and other equipment. Careful initial installation of lines also helps to prevent causes of interference.

b. Transposition of wires. Transposition of the wires of a telephone line, as shown in figure 63, is an effective method of reducing crosstalk or noise produced by inductive coupling between lines. Note that the wires of circuit 3-4 have been transposed, or made to cross over. As explained previously, the closer the wire is to the center of the magnetic field of the adjacent circuit, the greater is the emf induced in it. By transposition of the wires, however, a greater emf is induced in parts of wires E_{3A} and E_{4B}. Similarly, a smaller emf is induced in the other parts of wires E_{3B} and E_{4A}. This makes the resultant induced emf in wires 3 and 4 nearly equal. Since very little unbalanced emf now exists between the wires, the crosstalk current produced in circuit 3-4 is at a minimum. The same effect can be obtained by transposing the wires of circuit 1-2.

c. Capacity balance. Cables, since they often contain hundreds of pairs of wires, are particularly susceptible to crosstalk caused by capacity coupling between adjacent pairs. An important reason for this is the fact that the various wires exhibit different capacities to ground, making the system unbalanced to ground. One method of overcoming this is to equalize the capacities by transposing the various wires in the cable at points where one length of cable is spliced to an adjacent length of cable. Another method consists of equalizing the capacities by adding capacity to those pairs of wires that show

less capacity to ground than do other pairs. This capacity is added by connecting the wires on one end of a short length of a twisted pair to the cable pair and leaving the wires on the other end of the short length unconnected.

d. Use of repeating coils. In remote or rural areas, or in emergency installations for military uses, one-wire ground-return telephone circuits are often used. Since transposition is impossible on such circuits, they are much more susceptible to inductive interference from adjacent circuits. Even when connected directly to full metallic two-wire circuits, there is usually an objectionable amount of noise interference, since one side of the two-wire line must be grounded, creating an unbalance to ground. However, if the one-wire line is connected to the two-wire line through a repeating coil which isolates the two circuits, the two-wire line need not be grounded, and it operates as a balanced line. Ground-return circuits usually are replaced by two-wire circuits as soon as possible in order to avoid excessive interference.

e. Noise filters. Battery chargers and similar apparatus used to maintain batteries in common-battery systems are often the cause of hum, because the output voltage from these devices contains large amounts of energy at random frequencies. Filtering the output voltage by means of low-pass filters, which consist of series choke coils and shunt electrolytic condensers of fairly large capacity, removes the higher frequencies that lie in the voice-frequency range and, therefore, prevents noise interference from this source.

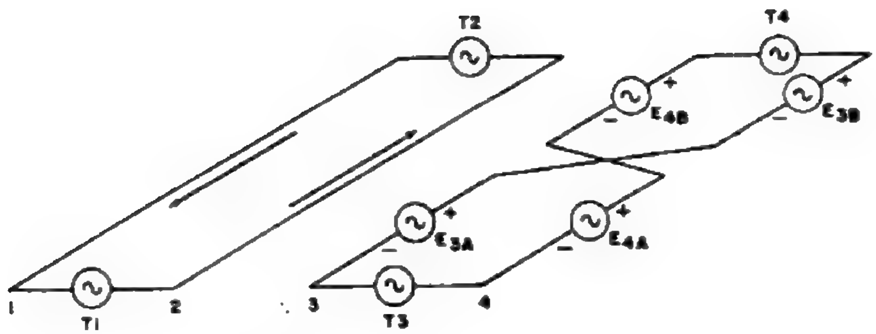


FIGURE 63. Reduction of Crosstalk by Transportation.

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65. Summary.

a. Telephone lines may be constructed in the form of cables, open wire, or field wire. Cables or field wire may be supported on poles similar to open wire lines, or may be laid on the ground. Cables may also be laid underground.

b. Transmission lines are considered electrically short if their length is shorter than the wavelength of the transmitted signal; they are considered electrically long if their length is approximately equal to or longer than the wavelength of the transmitted signal.

c. The electrical properties of a pair depend on its parameters, R, L, G, and C, all expressed in values per unit length (commonly 1 loop mile) and on the frequency of the transmitted current. For an electrically short pair, the parameters may be treated as distributed.

d. The characteristic impedance, Z_O, of a line is equal to the impedance that must terminate the line in order to make the input impedance equal to the terminating impedance. On a pair that is extremely long, the input impedance will equal the characteristic impedance of the line irrespective of the terminating impedance.

e. The characteristic impedance of a pair depends on the parameters of the pair and on the frequency, but it is independent of the length of the pair. The resistive component of the characteristic impedance is generally high at low frequencies and falls off with increasing frequency, approaching a value equal to L/C at high frequencies. The reactive component also starts out high at low frequencies and decreases at the higher frequencies. The characteristic impedance of a pair may be obtained from the measured open-circuit and short circuit impedances by the formula,

$$Z_O = Z_{OC}Z_{SC}$$

f. Maximum power is transferred from a source to a load over a transmission line when the line is terminated in its characteristic impedance.

g. Attenuation is the term used to express the power loss in a line. The attenuation of a line is measured in dB and can be calculated by using the relationship,

$$\text{attenuation in dB} = 10 \log. \frac{\text{input power}}{\text{output power}}.$$

h. The attenuation of any pair depends on the parameters R, L, G, and C of the line and on the frequency. Sometimes G or L, or both, are small enough to be negligible.

i. The loading of a transmission pair improves its response by increasing its series inductance. This may be accomplished by use of loading coils (lumped loading), or by wrapping the conductors with a tape or wire of magnetic material (continuous loading).

j. Cables and field wires are loaded by means of loading coils for military applications.

k. Interference in telephone circuits is of several kinds. Among natural causes may be listed lightning and other natural atmospheric disturbances. Among other causes may be listed interference from adjacent telephone circuits, possibly in the form of intelligible crosstalk or noise, and interference from nearby power or electric railway lines usually in the form of noise.

l. Crosstalk and noise may be produced by magnetic, conductive, and capacitive coupling between adjacent circuits.

m. Interference may be minimized by careful installation of the line, by transpositions of the wires of the line, by balancing the line capacitances, and by proper maintenance of equipment.

CHAPTER 7

SPECIAL CIRCUITS

66. Introduction.

This chapter covers single-line telephony and some of the elementary methods of obtaining an extra voice channel over a telephone line as used in early long distance telephony. These methods, referred to as multiplexing, are in use today in commercial and military systems, although they gradually are being replaced by more advanced techniques.

67. Single-Line Telephony.

Single-line telephone circuits may be full-metallic circuits or ground-return circuits, depending on the type of physical connection provided between the two telephone sets.

a. Full-metallic telephone circuit. This circuit is one in which two conductors are used to interconnect the telephone sets (chs. 4 and 5). It has the advantage of permitting transposition of wires as a means of overcoming inductive interference. For this reason, full-metallic circuits are used almost exclusively in military applications.

b. Ground-return telephone circuit. Figure 64 shows a ground-return telephone circuit. Only one wire is used to connect telephone sets T1 and T2; the other terminal of each set is returned to ground.

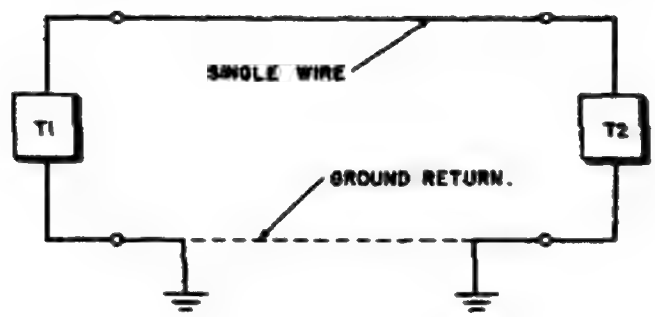

FIGURE 64. Ground Return Telephone Circuit.

(1) One advantage of this type of circuit is that it is more economical to construct than a full-metallic circuit, since it requires only half as much wire. Other advantages are the relative ease with which the circuit may be installed, and its lower line resistance (if the ground connections are made carefully). Lower line resistance means lower attenuation and more efficient transmission. Because of these advantages, ground-return telephone circuits still are used in rural areas, especially those where interference from power lines is not an important factor.

For emergency operation, the two conductors of an ordinary field wire can be connected and used as a single wire in order to extend the talking range of a telephone circuit.

(2) The disadvantages of ground-return circuits include their susceptibility to inductive interference from power lines, variations in operation which may result from differences in ground potential at different points, and the possibility of additional noise produced by faulty ground connections. Although ground-return circuits are not suited particularly to telephone communication, they have considerable application in military telegraphy, and also may be used for ringing circuits in telephony.

68. Simplex Circuit.

A simplex circuit is one in which a ground-return telephone or telegraph circuit is superimposed on a full-metallic circuit in order to obtain an extra channel. Of course, provision must be made for preventing interaction or interference between the two circuits. The principle of operation of a simplex circuit is explained later in this paragraph.

a. Repeating coils. In order to obtain the required isolation of the simplex and metallic circuits, repeating coils are used. A, figure 65, illustrates one type of coil used in switchboards of newer types because it is small, light, and efficient. The two upper terminals on the frame, marked SWITCHBOARD, are connected to the switchboard line terminals. The two outside bottom terminals, marked LINE, are connected to the incoming trunk line. The center bottom terminal, marked TELEG, is connected to one terminal of the telephone or telegraph set that is being operated on a simplex circuit. The symbol used to represent this type of repeating coil in schematic diagrams is shown in B. In this symbol, the switchboard terminals are designated by SB_1 and SB_2 the line terminal by L_1 and L_2 and the telephone or telegraph set by T. Repeating coils used with simplex circuits are highly efficient transformers of 1-to-1 ratio. The primary is identical with the secondary, each consisting of two balanced windings in series. The resistance of each of these four windings is 21 ohms. The only physical difference between them is that the secondary has a center terminal, T, connected to the junction of its two windings. Repeating coils installed at a switchboard are mounted either above or below the terminal strip. They are mounted so that they are accessible for maintenance, but they are protected from moisture or accidental injury. Figure 66 shows the position of a repeating coil in a line terminating and simplex panel.

The coil has the 1-to-1 turns ratio used in simplex circuits. Input to the unit is by way of the protectors, which are open-space cutouts used to protect the unit against excessive voltages induced in the connected line by lightning and other extraneous disturbances.

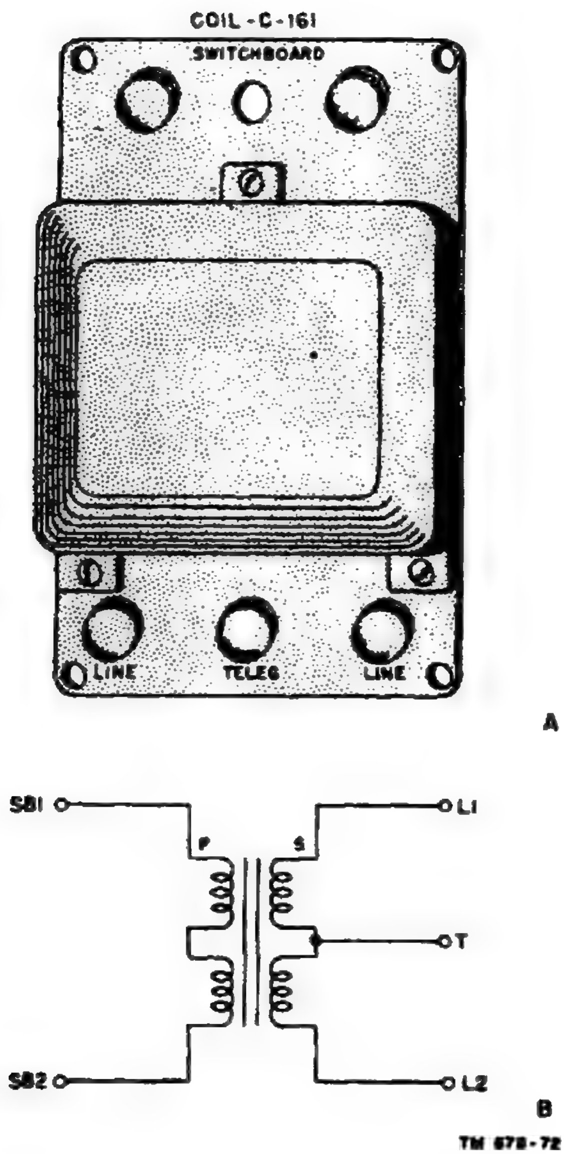

FIGURE 65. Typical repeating coil and symbol.

b. Operation. Figure 67 is a schematic diagram of a simplex telephone circuit superimposed on a metallic telephone circuit. Telephone sets T1 and T2 are connected to the metallic two-wire line by means of repeating coils RC1 and RC2, respectively. These two sets operate as a two-way full-metallic telephone system. By means of the repeating coils, an additional telephone circuit, or branch, is provided. This branch consists of telephone sets T3 and T4, and one terminal of each is connected to the center terminal on the secondary of its associated repeating coil. The other terminal is connected to a good ground, to furnish the return path for the current in the branch. The additional circuit thus provided is called a simplex circuit, and the metallic circuit on which it is superimposed is said to be simplexed by the ground-return circuit.

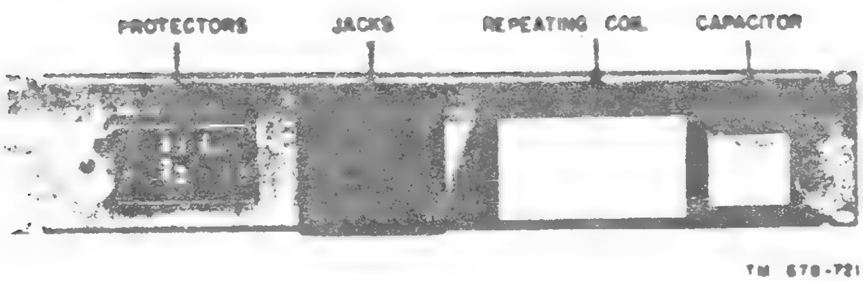

FIGURE 66. Line Terminating and Simplex Panel.

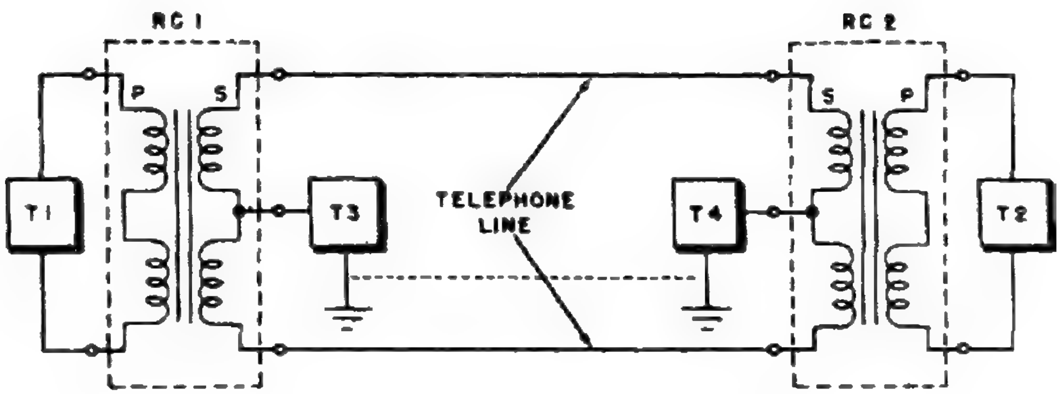

FIGURE 67. Simplex Telephone Circuit.

69. Current Paths in Simplex Circuit.

The function of the repeating coils which permit a metallic circuit to be simplexed without interference between the two circuits can be explained by reference to figure 68, in which the paths of the metallic-line currents, or side-circuit currents, are indicated by solid-line arrows and those of the simplex circuit by broken-line arrows.

a. Path of side-circuit current. Assume that a conversation is taking place between telephones T1 and T2 (fig. 68). Also assume an instant of time when the pulsating current in the primary of the induction coil of transmitter T1 flows in the direction indicated by the solid-line arrows. This current induces an emf in the secondary of RC1 and causes a corresponding current to flow in the secondary of repeating coils RC1 and RC2, as shown by the solidline arrow. Note that the secondary windings of the two repeating coils are connected by the two wires of the metallic line, thus furnishing a closed current path. The current flowing through the secondary winding of RC2 induces a corresponding emf in the primary which produces a current in the primary winding. Since telephone T2 is connected to the primary of RC2, this current flows through the receiver of T2, and results in the reproduction of the sound which originated in the transmitter of T1.

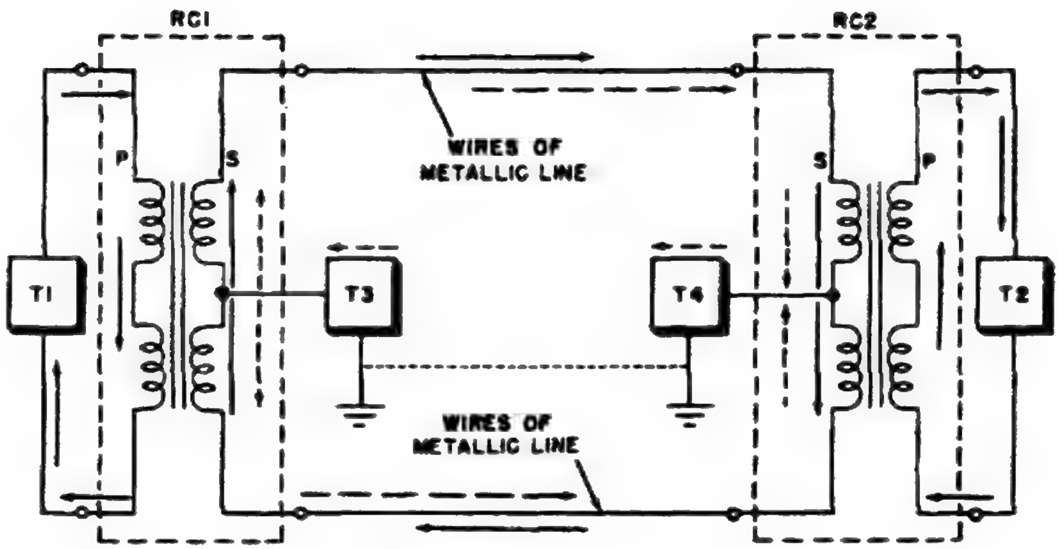

FIGURE 68. Current Paths in Simplex Circuit.

b. Path of simplex-circuit current.

(1) At the same time that this conversation is taking place, a person at telephone T3 may communicate with telephone T4 (fig. 68). The voice current at the center terminal of the secondary of RC1 divides equally into the two windings of the secondary of RC1, as shown by the broken-line arrows. Since equal currents flow in opposite directions through the two windings, no emf is induced in the primary of RC1, and no voice current flows in the receiver of T1. The conversation originating in T3 therefore is not heard in T1.

(2) The voice current flows through both wires of the metallic line, however, as indicated by the broken arrows. The current flowing up through the top winding of the secondary of RC1 flows through the upper line and through the top winding of the secondary of RC2. Similarly, the current flowing down through the bottom winding of the secondary of RC1 flows through the lower line and through the bottom winding of the secondary of RC2. These two currents join at the center terminal of RC2 and flow through the receiver of telephone T4. The path is completed through ground, as indicated by the dashed line. Just as the two windings of the secondary of RC1 induce neutralizing (canceling) emf 's in the primary of RC1, the two currents in the windings of the secondary of RC2 induce neutralizing emf 's in the primary of RC2 is zero, no current resulting from the conversation between T3 and T4 flows into the receiver of T2. Consequently, a means is provided of carrying on two independent conversations without mutual interference on a single metallic circuit.

c. Line balancing with simplex circuit.

(1) The operation of a simplex circuit takes place without mutual interference only if the repeating coils have identical windings, and if the wires of the metallic line have the same impedance. It may be assumed that proper design and manufacture of the repeating coils eliminates any unbalance resulting from the coils. However, interference caused by different impedances in the two wires of the metallic circuit may be troublesome. The main cause of unbalance in the lines of field-wire circuits is caused by poor splices, which may introduce a high resistance into one side of the circuit. Another cause of unbalance is improperly taped splices and worn and damaged insulation, which may result in excessive leakage from one side of the circuit to ground, particularly when the wires are wet.

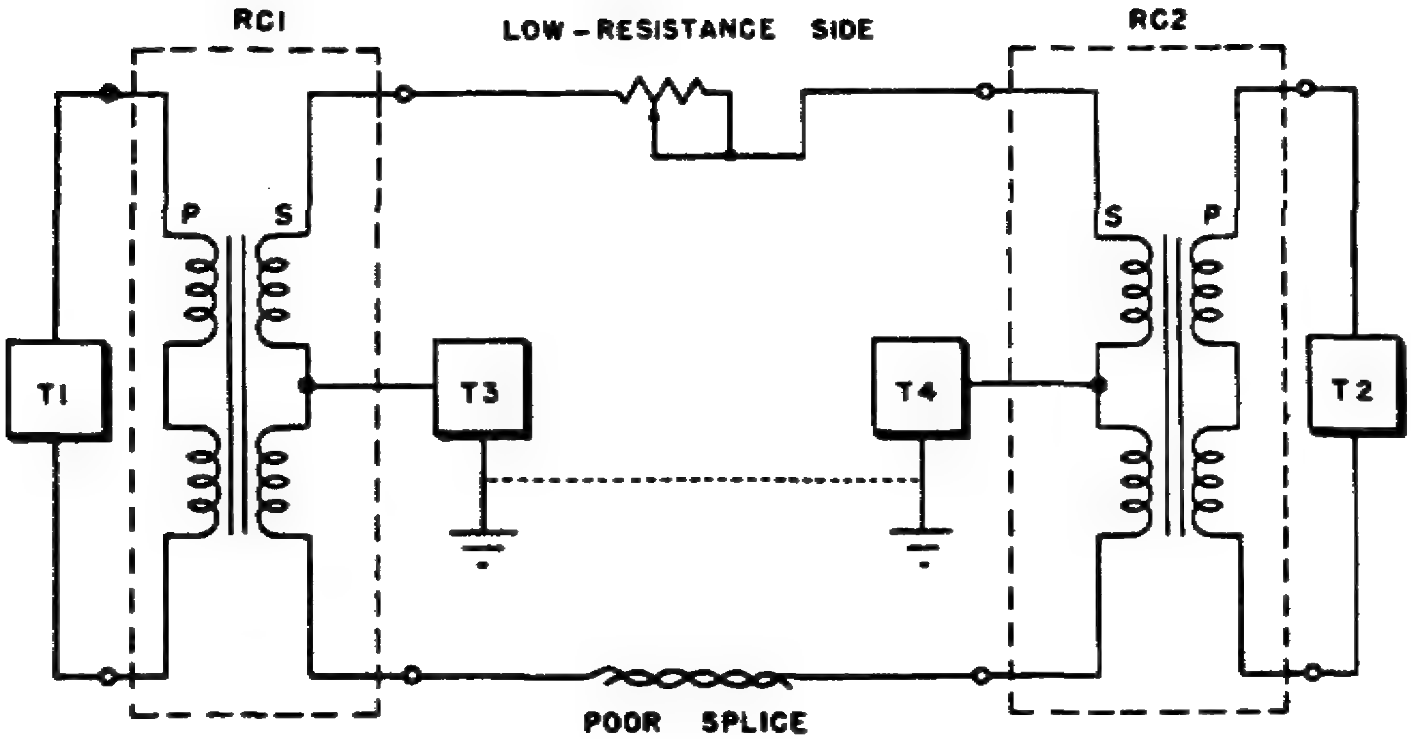

FIGURE 69. Balancing Simplexed Line

(2) Interference from a poor splice may be reduced to a tolerance level by introducing an additional loss in the circuit; this is accomplished by using a rheostat in the low-resistance side of the line (fig. 69). The low-resistance side is ascertained by trial; that is, the rheostat is inserted first in one side of the line, and then in the other. When placed in the low-resistance side, adjustment of the rheostat markedly equalizes the loss on each side of the line. When these losses are equal, interference drops to a minimum.

70. Advantages and Limitations of Simplex Circuit.

a. Advantages. One of the obvious advantages of the simplex circuit which make it useful in military applications where time is an important factor is that it adds telephone or telegraph channel to a two-wire line without interference, thus effecting a considerable saving of material and maintenance. Another advantage is the comparative ease of installation.

b. Limitations. In spite of the considerable saving in time, material, and personnel obtained with simplex circuits, they usually are not used to provide an additional telephone channel. The ground-return makes the line susceptible to interference from noise and crosstalk. Also, the ground-return circuit signal is more susceptible to interception by an enemy. Telegraph circuits, however, operate effectively on a ground-return system, and simplex circuits frequently are used to provide an additional telegraph channel on a two-wire metallic line.

71. Phantom Telephone Circuit.

a. A phantom circuit provides an additional telephone channel on two 2-wire metallic circuits. Side circuit Nos. 1 and 2 in figure 70 are the two 2-wire metallic circuits of such an arrangement. These two circuits, together with the phantom circuits, constitute a phantom group.

b. The phantom group contains six repeating coils located at the central office. These coils are similar to those used in simplex circuits. Repeating coils RC1 and RC2 are connected in circuit No. 1 at the line terminals of the switchboard. Telephone sets T1 and T2 are connected at the switchboard to the switchboard terminals of RC1 and RC2, respectively. Similarly, repeating coils RC3 and RC4 are connected inside circuit No. 2, and telephone sets T3 and T4 are connected at the switchboard to the respective switchboard terminals of these repeating coils. The phantom circuit uses two additional repeating coils, RC5 and RC6. One line terminal of RC5 is connected to the center terminal of RC1, and the other terminal is connected to the center terminal of RC3. Similarly, the two line terminals of RC6 are connected, respectively, to the center terminals of RC2 and RC4. The center terminals of RC5 and RC6 are not connected to any other point. Telephone set T5 is connected at the switchboard to the switchboard terminals of RC6. T5 and T6 also may represent telegraph sets instead of telephones, so that phantom operation provides either additional telephone or telegraph channels. It is also possible to construct a phantom group without the use of repeating coils RC5 and RC6 by connecting set T5 directly to the center terminals of RC1 and RC3, and connecting set T6 to the center terminals of RC2 and RC4. This arrangement affords economics in initial cost and maintenance, since it eliminates two repeating coils, but it is more susceptible to inductive interference..

72. Analysis of Phantom Circuit.

a. Path of phantom-circuit current.

(1) As in the simplex circuit, the center-tapped iron-core repeating coil used in a phantom group prevents the voice currents of the phantom circuit from interfering with those of the side circuits. Assume that at a given instant the phantom circuit in figure 70 is operating from left to right; that is, a person at telephone set T5 is talking to someone at telephone T6. If the voice current in the primary winding of RC5 is assumed to flow down at this instant, the emf induced in the secondary will cause a corresponding current to flow up

through the secondary (broken arrows). This current flows up to the center terminal of the secondary of RC1, where it divides equally into the two branches, since the branch resistances of a perfectly balanced line are equal. Since the current in the upper winding of the secondary of RC1 is flowing up, and an equal current in the lower half is flowing down (broken arrows), the resultant voltage across the secondary is zero. Therefore, no corresponding emf is induced in the primary of RC1, and no corresponding current flows in the receiver of set T1.

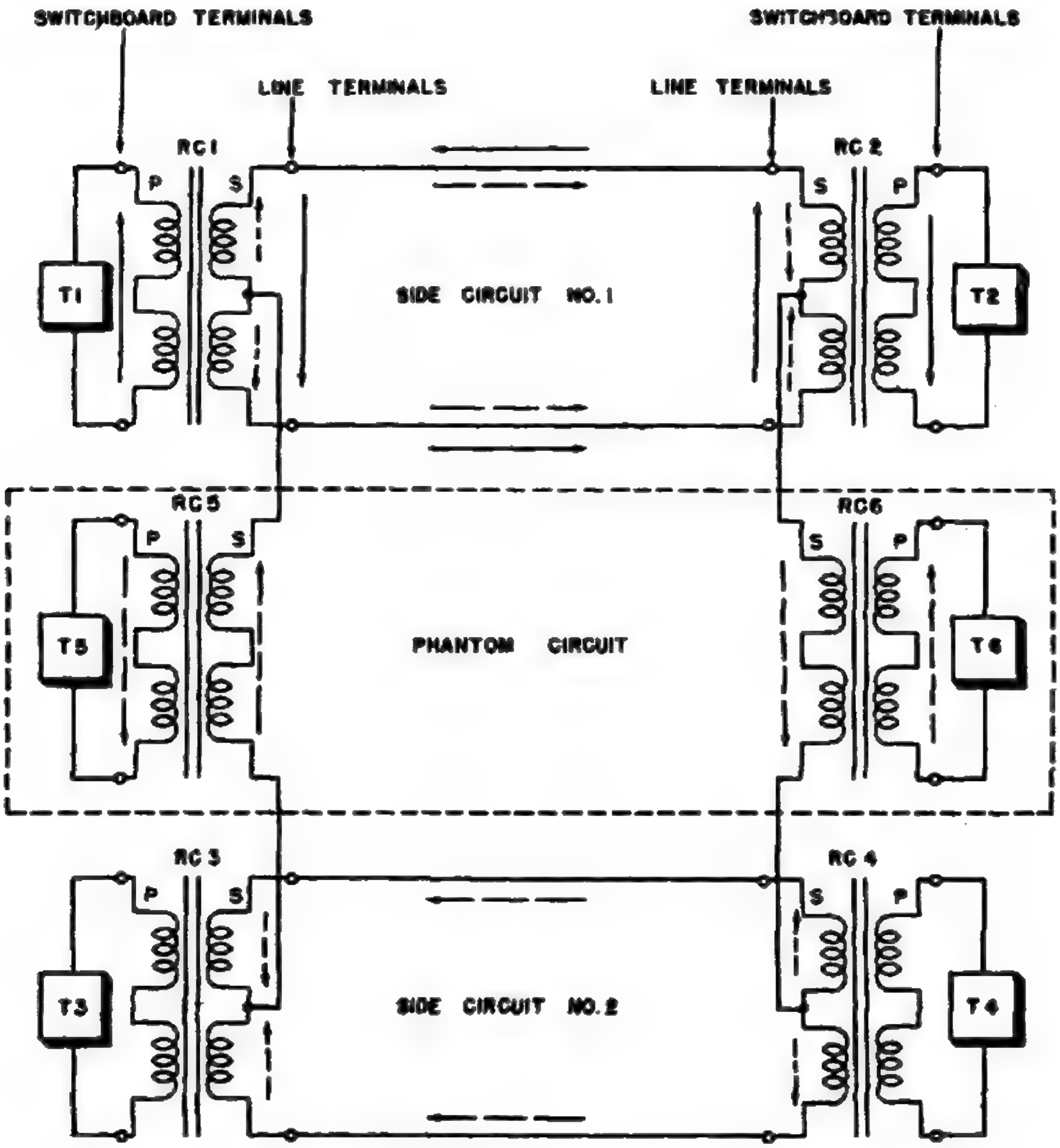

FIGURE 70. Phantom Telephone Circuit

(2) The currents continue to the right in the metallic wires of the line of side circuit No. 1 and join at the center terminal of the secondary of RC2 (broken arrows). Since the current in the top wire flows down through the upper winding, however, while an equal current in the bottom wire flows up through the lower winding of the secondary, the same canceling effect occurs as in RC1. Therefore, no corresponding current flows in the primary of RC2 or in the receiver of T2.

(3) The combined current flows out of the center terminal of RC2 and down through the secondary of RC6 (broken arrow). This is the same total current that flows up through the secondary of RC5. A corresponding current therefore flows in the primary of RC6 and through the receiver of set T6, reproducing the sound originally introduced at the transmitter of T5.

(4) By a similar analysis, the path of current can be traced through the secondary of RC4, the wires of the line of side circuit No. 2, and the secondary of RC3. Since the same canceling occurs in these repeating coils, no phantom circuit current flows in the primaries of these coils or in sets T4 and T3.

b. Path of side-circuit current.

(1) The use of repeating coils in a phantom group also prevents the side-circuit currents from interfering with those of the phantom circuit. This can be seen by following the solid-line arrows from set T1 through side circuit No. 1 and set T2, and back again, to T1 (fig. 70). Assume an instant of time when a voice current originating in the transmitter of T1 flows up through the primary of RC1. An emf is induced in the secondary, causing a corresponding current to flow down through the entire secondary. None of this current flows out through the center terminal of RC1, and consequently no part of the current flow through the secondary of RC5 or RC3. No interference exists, therefore, between set T1 and sets T5 and T3.

(2) The current flows to the right through the bottom wire of side circuit No. 1 and up through the secondary of RC2, the path being completed through the top wire. Again, no part of this current flows out of the center terminal of RC2 or through the secondaries of RC6 and RC4. Therefore, no corresponding current flows through the receivers of sets T6 and T4, and there is no interference in these sets.

(3) The current in the secondary of RC2, however, induces an emf in the primary. A corresponding current therefore flows down through the primary of RC2 and through the receiver of T2, reproducing the sound introduced at the transmitter of T1.

(4) Similar analysis can be made for conversations originating in T2, T3, and T4. They will show that the operation of a phantom group prevents interference between side circuits and the phantom circuit. Of course, perfect operation requires perfect balance of the lines of the side circuits, and well balanced repeating coils.

73. Advantages and Limitations of Phantom Circuits.

a. Advantages.

(1) The most important advantage of the phantom circuit over the simplex circuit is the elimination of the ground return. This gives an additional telephone channel with freedom from the inductive interference to which ground-return circuits are susceptible. Phantom circuits are used to obtain an additional telegraph channel when good ground connections--always necessary for its operation in a simplex circuit--are difficult to obtain. Phantom circuits often are used in teletypewriter communications.

(2) When the side circuits of a phantom group are composed of cables instead of open-wire lines, it is possible to reduce attenuation and obtain distortionless operation by using loading coils. These coils are arranged so that the currents in the phantom circuit produce aiding magnetic fluxes in the core of the phantom loading coil, but opposing fluxes in the cores of the loading coils in the side circuits. In this way, the phantom currents do not affect the side circuits, nor do the side-circuit currents affect the phantom circuit. Of course, the loading coils must be designed, constructed, and installed carefully, to maintain a perfect balance and prevent crosstalk between the phantom and side circuits.

b. Limitations. For the circuits of a phantom group to operate without interference, the two metallic circuits upon which the phantom circuit is superimposed must be well balanced. The method of balancing a line by use of a rheostat in the low-resistance side of an unbalanced line can be used also in the side circuits of a phantom group. Also, for operation without interference, the repeating coils must be identical and installed properly. When these conditions are satisfied, a phantom-group operation has advantages that

out-weigh its limitations, so that it occupies an important place in military communications.

74. Simplexed-Phantom Circuit.

a. Description. A circuit that combines the principles of both simplex circuits and phantom groups is called a simplexed-phantom circuit (fig. 71). It consists of two side circuits and a phantom circuit, comprising a phantom group, with the addition of a simplex circuit accommodating the operation of telegraph sets T7 and T8.

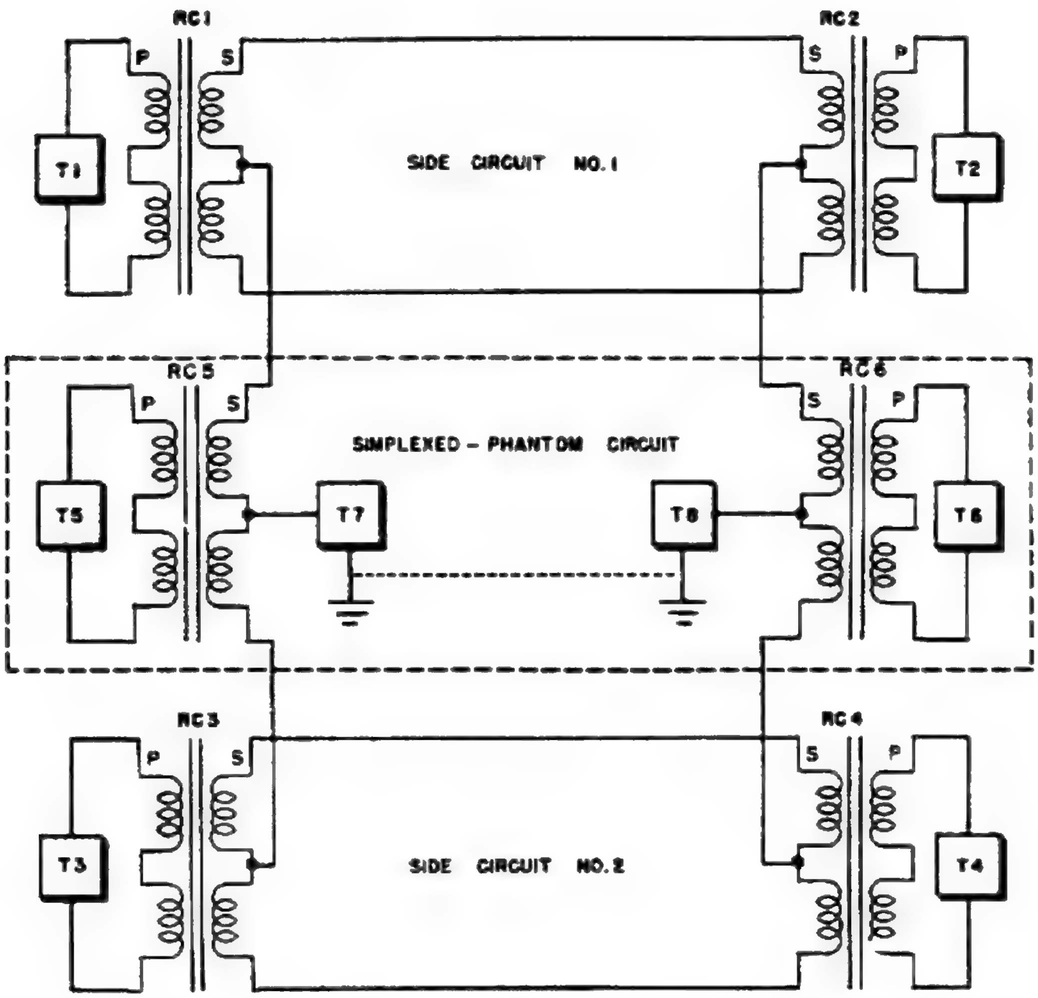

FIGURE 71. Simplexed Phantom Circuit.

b. Operation. The simplexed leg of the simplexed-phantom circuit contains a ground-return circuits which permits transmission of telegraph signals between telegraph instruments T7 and T8. The connections of these instruments are similar to those of the simplex circuit. One terminal of set T7 is connected to the center terminal of the secondary of repeating-coil RC5, and one terminal of set T8 to the center terminal of secondary RC6. The other terminal of each set is grounded as effectively as possible, to furnish the return path. By using an analysis similar to that given in the discussion of simplex and phantom circuits, the currents of the simplex leg, the phantom circuit, and the side circuit can be traced. Such an analysis will show that a signal originating in T1 is reproduced only in T2, one originating in T3 is reproduced only in T4, one originating in T5 is reproduced only in T6, and a telegraph impulse originating in T7 is reproduced only in T8. In the usual operation of a simplexed-phantom circuit, the side circuits and the phantom circuit are used to obtain three telephone channels, since these circuits involve full metallic-line operation. The simplex leg provides a telegraph channel.

c. Limitations. The same general limitations discussed in connection with simplex and phantom circuits, and concerned primarily with the maintenance of perfect balance in the metallic lines and repeating coils, apply to simplexed-phantom circuits. The existence of four channels in a simplexed-phantom circuit makes perfect balance even more critical than in the other types. For this reason, and because they are more difficult to maintain in the field, simplexed-phantom circuits often are not used in forward areas of operation.

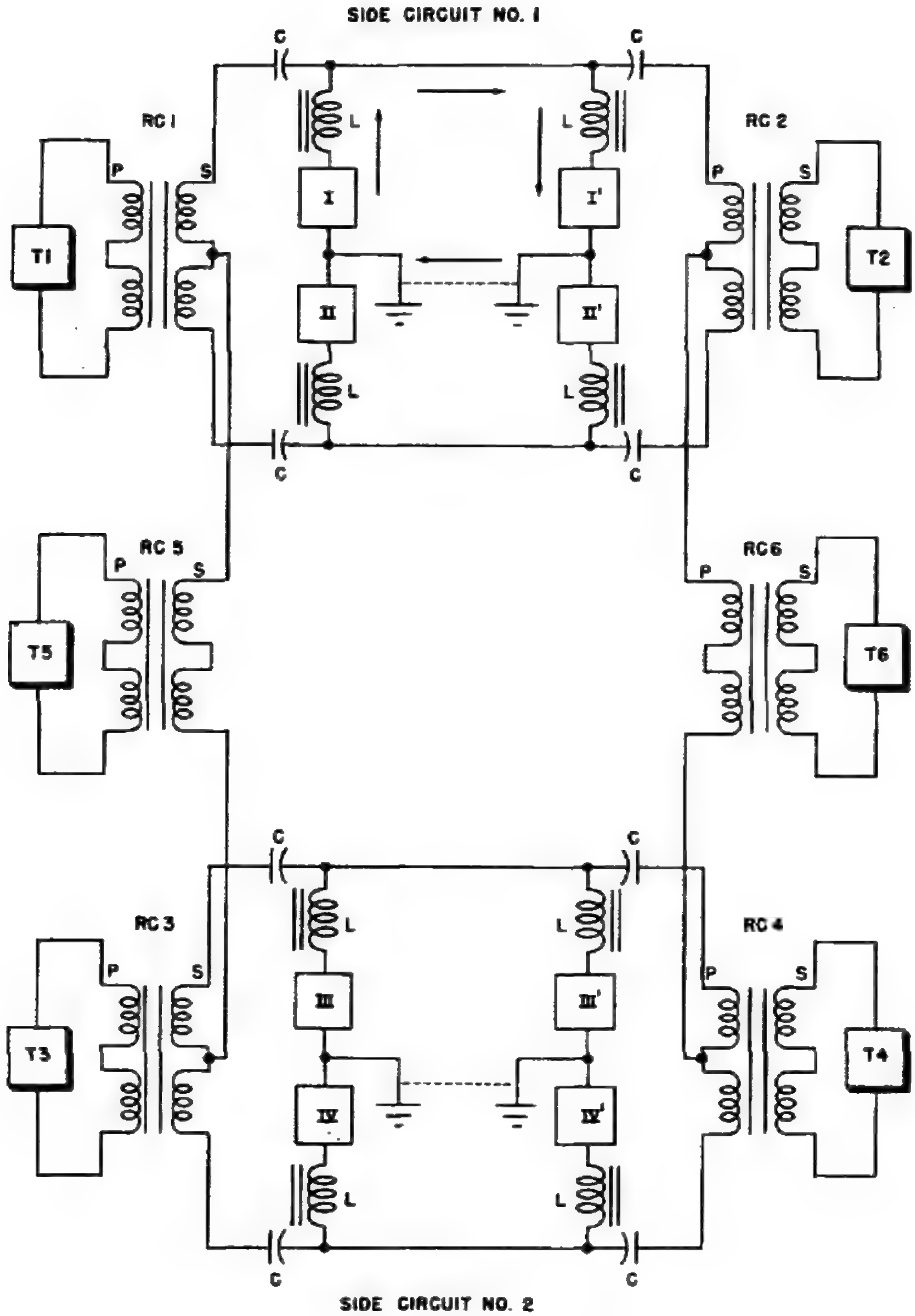

FIGURE 72. Composite Circuit

The attenuation of the telegraph impulses is lower than in the case of the simplex circuit, since the wires of the two side circuits are effectively in parallel and thus offer less resistance to current flow. (An interesting feature of the operation of a simplexed-phantom circuit is the fact that the telegraph channel operates even if three of the four lines are broken, since only one wire is needed to provide a complete path in a ground-return circuit.)

75. Composite Circuit.

a. Description. Another type of circuit that provides simultaneous telephone and telegraph service is the composite circuit shown in figure 72. This circuit permits the simultaneous operation of three telephone channels over a phantom group, and four additional telegraph channels, two in each side circuit. The telegraph channels operate as ground-return circuits. They are indicated on the left side of the circuit by the designations I, II, III, and IV.

b. Operation. In addition to the two metallic lines and the six repeating coils required for phantom-group operation, the composite circuit requires eight capacitors and eight coils, indicated by C and L. These elements act as high-pass and low-pass filters, respectively. The turns ratio of the six repeating coils is not always 1-to-1.

(1) In order to comprehend the need for these capacitors and coils, it must be understood that a telegraph channel can operate over a path that passes frequencies up to 100 hertz, whereas a telephone channel can operate over a band of from 200 to 3,000 hertz, approximately. It must be remembered, also, that a capacitor offers low impedance to high frequencies, but relatively high impedance to low frequencies, and that a coil, inversely, offers low impedance to low frequencies, but relatively high impedance to high frequencies. Because of this, telephone impulses originating in the telegraph set on the left side of telegraph channel I pass through coil L, through the central portion of the upper wire of side circuit No. 1, through the second coil and the set on the right-hand side of channel I, and back to its origin through the ground-return path. This telegraph current is blocked by the four capacitors in the line of side circuit No. 1, and thus is prevented from reaching any of the six telephone sets. Operation is similar to each of the other three telegraph channels.

(2) Similarly, a telephone conversation originating in telephone set T1 is passed by the capacitors in the line of side circuit No. 1, and, by the transformer action of the repeating coils, is heard in set T2 (fig. 72). Since

these currents are blocked by the coils in series with the telegraph sets in channels I and II, however, they are prevented from reaching the sets. For example, if the condensers are assumed to have individual capacitances of ZuF, and the coils to have inductances of .5 henry each, the capacitive reactance of each capacitor at a frequency of 200 hertz is approximately 400 ohms, and the inductive reactance of each coil at this frequency is approximately 628 ohms. At 1,000 hertz, the capacitive reactance is only 80 ohms, and the inductance reactance is 3,140 ohms. At 50 hertz, however, the capacitive reactance is 1,600 ohms, and the inductive reactance is only 157 ohms. Because of the basic operation of these filters, therefore, the three telephone channels and four telegraph channels may be operated simultaneously without mutual interference. Low-frequency ringing cannot be used on the telephone channels because of the attenuation that occurs below 200 hertz. Instead, interrupted 1,000 hertz ringing is used.

(3) Figure 73 shows a line terminating and composite panel which contains a composite circuit and its associated components.

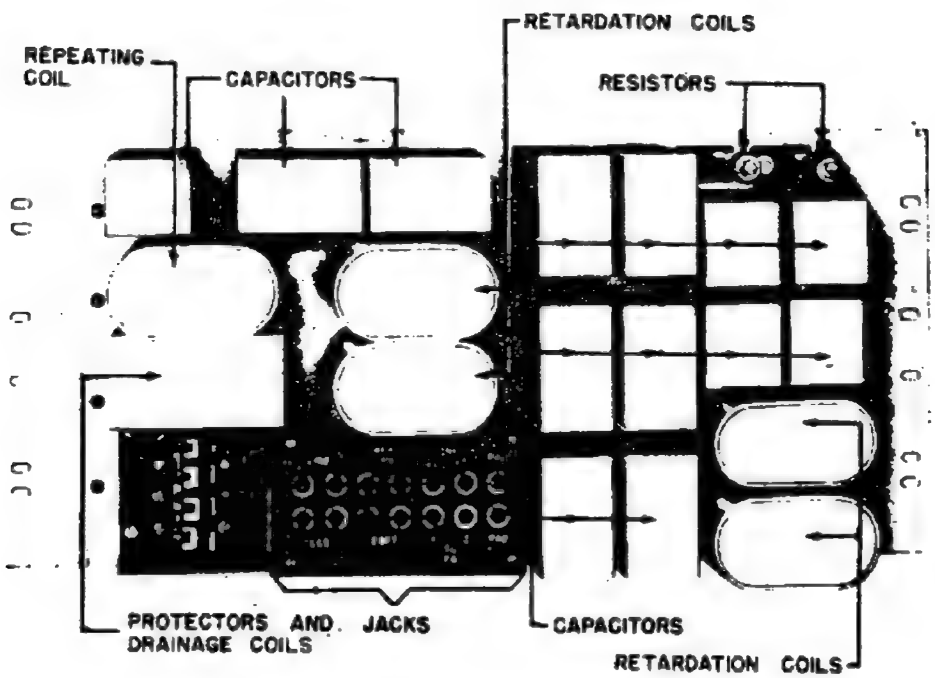

FIGURE 73. Line Terminating and Composite Panel

c. Limitations of composite circuit. The operation of the composite circuit is subject to the same limitations as the simplex and phantom circuits. The repeating coils and lines must be balanced perfectly to prevent interference among the various channels. Furthermore, the capacitors and coils comprising the filters must be selected carefully and installed in order to insure proper separation of low and high frequencies in the telegraph and telephone channels.

76. Summary.

a. Single-line telephony is a system of telephone communication in which two telephone sets are connected by a single transmission line.

b. Single-line telephone circuits may be full-metallic, involving a two-wire line, or they may be ground-return, in which only one wire is used, the circuit being completed through the ground.

c. Full-metallic circuits are less susceptible to inductive interference than ground-return circuits, and therefore they are preferred for telephone communication.

d. Ground-return circuits operate well for telegraph communication, and for signaling (ringing) circuits in telephone communication.

e. A simplex circuit is a ground-return circuit superimposed on a full-metallic circuit. It permits the addition of either one telephone or one telegraph channel on an existing two-wire telephone channel. It is used frequently to provide an additional telegraph channel.

f. Operation of the simplex circuit involves the use of repeating coils at each end of the metallic line. These coils are efficient 1-to-1 iron-core transformers, consisting of two equal primary windings in series and two equal secondary windings in series. The usual resistance of each of the four windings is 21 ohms.

g. Perfect balancing of the repeating coils and the line of the metallic circuit insures efficient operation of a simplex circuit, without mutual interference between the simplex leg and metallic circuit.

h. If faults on the line make one wire of greater resistance than the other, balance can be obtained by inserting a rheostat in the low-resistance side, and varying it until the resistances of both sides are equal.

i. A phantom circuit provides a means for obtaining an extra channel over two full-metallic circuits. The additional channel thus obtained is called the phantom circuit. It may be used either for telephone or telegraph. The two full-metallic channels are called side circuits, and the entire combination is called a phantom group.

j. Efficient operation of a phantom group depends on the use of six repeating coils which must be perfectly balanced. This prevents interference between the current in the phantom circuit and the currents in the side circuits.

k. Cables used in the construction of phantom circuits may be loaded by the use of specially designed loading coils. These reduce attenuation and improve the performance of the phantom group.

l. A simplexed-phantom circuit extends the application of a phantom group by providing an additional telegraph channel. This channel is a simplex circuit superimposed on the phantom circuit of the group.

m. Perfect balance in the repeating coils and the lines of the side circuits is required also in a simplexed-phantom circuit.

n. Simultaneous telephone and telegraph communications also is provided in the composite circuit. This circuit permits four additional telegraph channels to be superimposed on a phantom group without mutual interference. Its operation is based on the use of capacitors in series with the lines of the side circuits, and coils in series with the telegraph instruments that are bridged across the lines of the side circuits. The condensers and coils behave like high-pass and low-pass filters, respectively.

LESSON 3 EXERCISES

1. The term used to express power loss in transmission lines is called:

   a. resistance.
   b. impedance.
   c. attenuation.
   d. ohms.

2. Line power loss calculations are expressed as:

   a. ohms.
   b. watts.
   c. amps.
   d. decibels.

3. When field wire is "loaded" it usually increases the:

   a. talking range.
   b. shunt loss.
   c. capacitance.
   d. electrical length.

4. Attenuation is the term used to express the loss of power that occurs in a network or transmission line. This loss is attributed to:

   a. parallel resistance and shunt conductance.
   b. series resistance and shunt conductance.
   c. variations in power transfer.
   d. characteristic impedance.

5. The three main classes of transmission lines used in military telephone installations are:

   a. cables, field wire, and single conductor.
   b. field wire, single conductor, and open-wire lines.
   c. single conductor, open-wire lines, and cables.
   d. open-wire lines, cables, and field wire.

6. Assume that a change in the tactical situation requires the extension of a 20-mile wire circuit composed of twin-pair WD-1/TT strung on poles without insulators. By installing insulators, the length of this circuit can be extended to a maximum of:

a. 40 miles.

b. 50 miles.

c. 60 miles.

d. 70 miles.

7. The wavelength of a signal is determined by the velocity and the frequency of the signal. For example, the wavelength of a 1,500-cycle signal over an open-wire line is approximately:

a. 40 miles.

b. 120 miles.

c. 1/40 mile.

d. 1/120 mile.

8. One of the characteristics of a transmission line is its electrical length. The term <u>electrically short line</u> means that the length of the line is:

a. physically 1 mile or less in length.

b. greater than the transmitted signal wavelength.

c. equal to the transmitted signal wavelength.

d. less than the transmitted signal wavelength.

9. A communications-electronics (C-E) officer constructing a section of open-wire line has two sizes of copper conductor (104 mils and 128 mils) available for the job. The distributed constant which is the same value for either of the two conductors is the:

a. series resistance.

b. series inductance.

c. shunt capacitance.

d. shunt conductance.

10. Assume that you are required to determine the attenuation of a transmission line. If the input is 60 milliwatts and the output power is 12 milliwatts, the attenuation is:

a. 5 dB.
b. 7 dB.
c. 12 dB.
d. 48 dB.

11. A transmission line requiring minimum attenuation is being installed between stations A and B. The type of transmission line that has the lowest attenuation for a given distance is:

a. field wire.
b. open-wire line.
c. five-pair cable.
d. spiral-four cable.

12. Assume that the distortion of a voice-frequency signal in a transmission line is due to the unequal attenuation of the different frequencies. This distortion, as well as the attenuation, in the line can be reduced by the addition of:

a. series inductance.
b. parallel resistance
c. parallel capacitance.
d. series resistance.

13. Inductive coupling (fig. 63) between the conductors of a transmission line may cause crosstalk between adjacent circuits. One method used to reduce this crosstalk is to:

a. transpose and balance the capacitance of the lines.

b. install filters in the lines.

c. install repeating coils in the lines.

d. transpose the conductors of the lines.

14. One practice used to improve service on circuits that are conducted through cables is to splice short lengths of twisted pair wire to certain pairs in the cable. The purpose of this procedure is to:

a. provide continuous loading for the cable.

b. filter and reduce inductive coupling.

c. filter and reduce undesirable noise.

d. provide capacity balance between the pairs.

15. Assume that there are generators and battery chargers causing noise and humming on the transmission line. This disturbance can be reduced by installing:

a. low-pass filters.

b. loading coils.

c. repeating coils.

d. high-pass filters.

16. The ground-return telephone circuit shown in figure 64 is very seldom used in present military communications. One of the disadvantages that limits its use is the:

a. complexity of the installation.

b. high resistance per loop mile.

c. high initial cost of construction.

d. possibility of excessive noise from poor ground connections.

17. The circuit shown in figure 68 is providing two channels of communication. The voice currents of the simplex circuit are not heard in the metallic circuit because:

a. repeating coils transfer the emf in only one direction.

b. because voice currents go through the ground in a simplex circuit and not over the wire.

c. voice currents divide equally at the secondary center top thus inducing no emf in the secondary.

d. Voice currents in the secondary cancel the emf in the ground path.

18. The phantom group shown in figure 70 provides an additional telephone or telegraph circuit from two 2-wire circuits without using ground return. The number of repeating coils necessary for efficient operation with this arrangement is:

a. two.

b. three.

c. four.

d. six.

19. Assume that a type of circuit was installed in the central office telephone system to permit three telephones and four telegraph channels to be operated simultaneously. This type of circuit is known as a:

a. phantom group circuit.

b. composite circuit.

c. simplexed-phantom circuit.

d. metallic and ground-return circuit.

CHECK YOUR ANSWERS AGAINST LESSON 3 SOLUTION SHEET (PACE 193) AND MAKE NECESSARY CORRECTIONS.

LESSON 4

FUNDAMENTAL OF TELETYPEWRITER

OBJECTIVE:

Action:	You will explain the characteristics of the Baudot Code, identify terms used in teletype operation, identify symbols peculiar to telegraph operation and describe the four types of teletype circuits.
Conditions:	You will be given the lesson material and a lesson exercise sheet.
Standard:	You must correctly answer at least 17 of the 20 questions in the lesson exercise.
CREDIT HOURS:	2
TEXT ASSIGNMENT:	Read inclosed text
MATERIALS REQUIRED:	Pencil or pen
SUGGESTIONS:	None

CHAPTER 9

INTRODUCTION TO TELETYPEWRITER COMMUNICATIONS

77. Introduction to Teletypewriter Communications.

The purpose of this text is to explain some of the fundamental concepts and terms used in teletypewriter communications.

a. Telegraphy is a system of sending and receiving coded signals. Teletypewriter communication is telegraphy in which teletypewriters such as the one in figure 74 are used at the sending and receiving stations.

b. The block diagrams in figure 75 illustrate systems in which the teletypewriter and associated equipment can be used to send a message from one station to another.

(1) Direct current (dc) system (A, figure 75). In a dc system, the sending teletypewriter operator types a message. Direct current pulses are sent over a circuit to the receiving teletypewriter. The receiving teletypewriter automatically translates the coded pulses and types out the message. The pulse code and the kinds of pulses used in dc teletypewriter circuits are discussed in paragraphs 73 and 76 respectively.

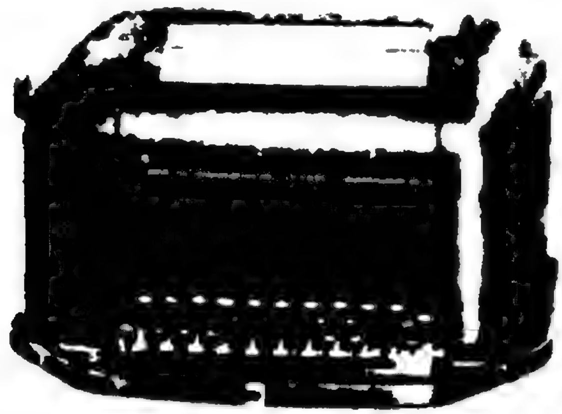

FIGURE 74. Typical Teletypewriter.

(2) Voice-frequency carrier system (B, fig. 75). In a typical voice-frequency system, the teletypewriter output goes to a voice-frequency telegraph terminal where it causes an oscillator to shift from one predetermined frequency to another higher or lower frequency, depending on the teletypewriter output. The voice-frequency output of the oscillator then goes to the receiving station. Existing telephone lines are often used to interconnect the sending and receiving stations although wire or radio may also he used. This type of operation is used for all multichannel systems.

(3) Single channel radio teletypewriter system (C, fig. 75). The voice-frequency output of the telegraph terminal goes to the transmitter in a radio terminal where it is sent to the receiving station.

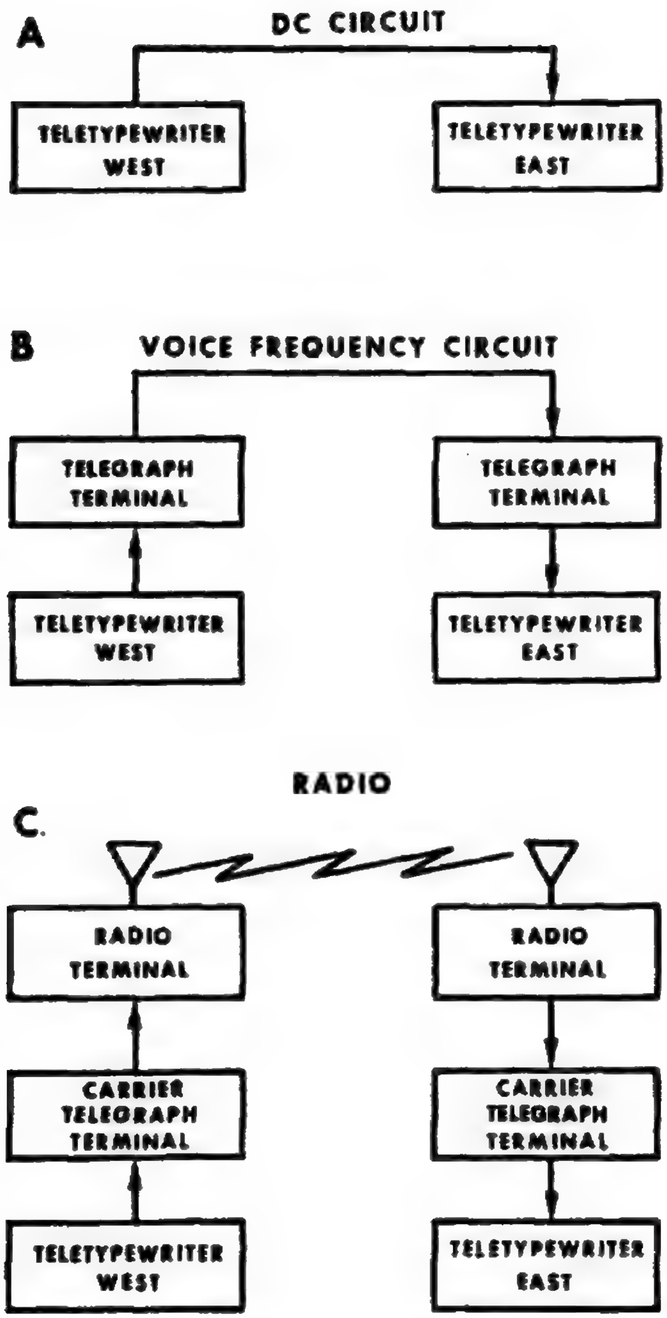

FIGURE 75. Types of Teletypewriter Communication Systems.

78. <u>The Teletypewriter Code</u>.

a. In teletypewriter communication the operator of the sending teletypewriter types the message on a special keyboard and the machine transmits coded combinations of current pulses (called <u>mark</u> and <u>space</u> pulses) for each character. The coded combinations of pulses is called the Baudot Code. It is also known as the 7.42-unit code and the Bell code.

b. The Baudot code is a five-unit, start-stop code. Each character (letter, number, etc.) is a combination of five intelligent pulses (marks and spaces), plus a <u>start</u> pulse and a <u>stop</u> pulse as shown in figure 76. The start and stop pulses start and stop the receiving teletypewriter to synchronize its operation with the sending teletypewriter. The start pulse is always a space and the stop pulse is always a mark.

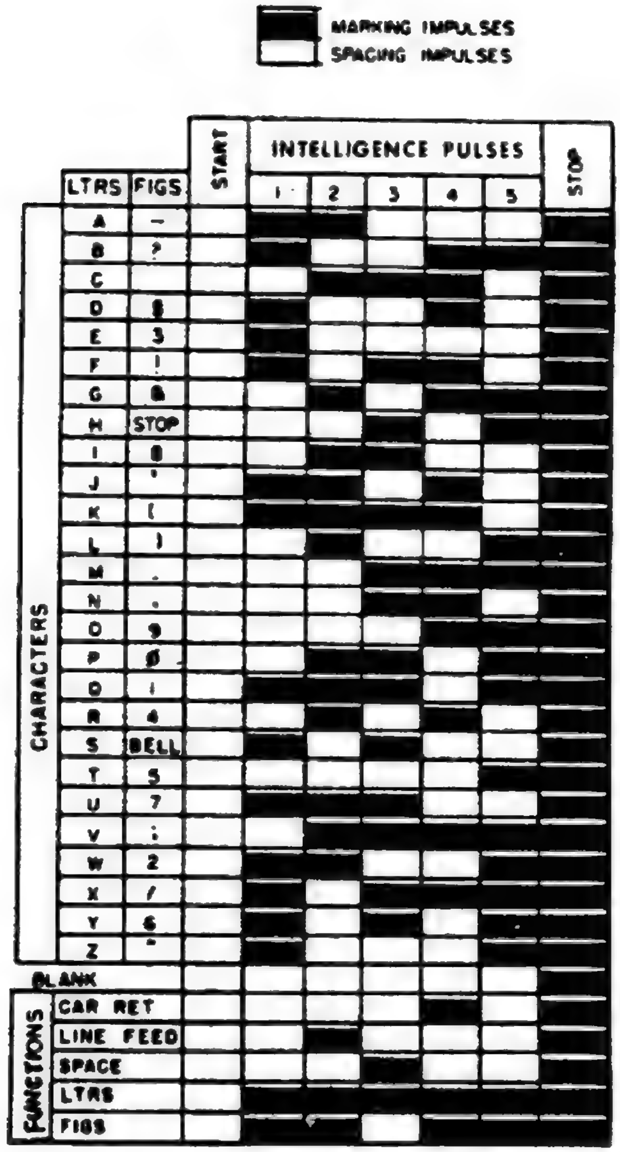

FIGURE 76. Baudot Code.

c. The start, intelligence, and stop pulses for the letter A are shown in A of figure 77. The series of pulses or pulse train that represent the word "ARMY" in shown in B of figure 77.

d. The pulse group code groups below the letter Z in the Baudot code table make the sending and receiving teletypewriters perform machine operations. For example, CAR RET, which stands for carriage return, returns the carriage of the teletypewriters to the extreme left for the beginning of another line of type. LINE FEED advances the paper page after each line is typed. SPACE moves the carriage one space for spacing between words. LTRS makes the machines shift to type letters of the alphabet, and FIGS makes the machine shift to type numbers and punctuation marks. Incidentally, the teletypewriters type everything in capital letters, because there is no provision in the Baudot code for representing lower case letters.

e. The sending operator uses the BLANK key to indicate a momentary pause in the transmission of a message. The BLANK key is also used when transmitting from American teletypewriter equipment into British equipment. The key must be depressed at the end of the message so that the British equipment can receive the last character.

79. Rate of Transmission in a Teletypewriter System.

a. Words per minute (WPM). It takes 22 milliseconds to transmit the start pulse, 22 milliseconds for each of the intelligence pulses, and 31

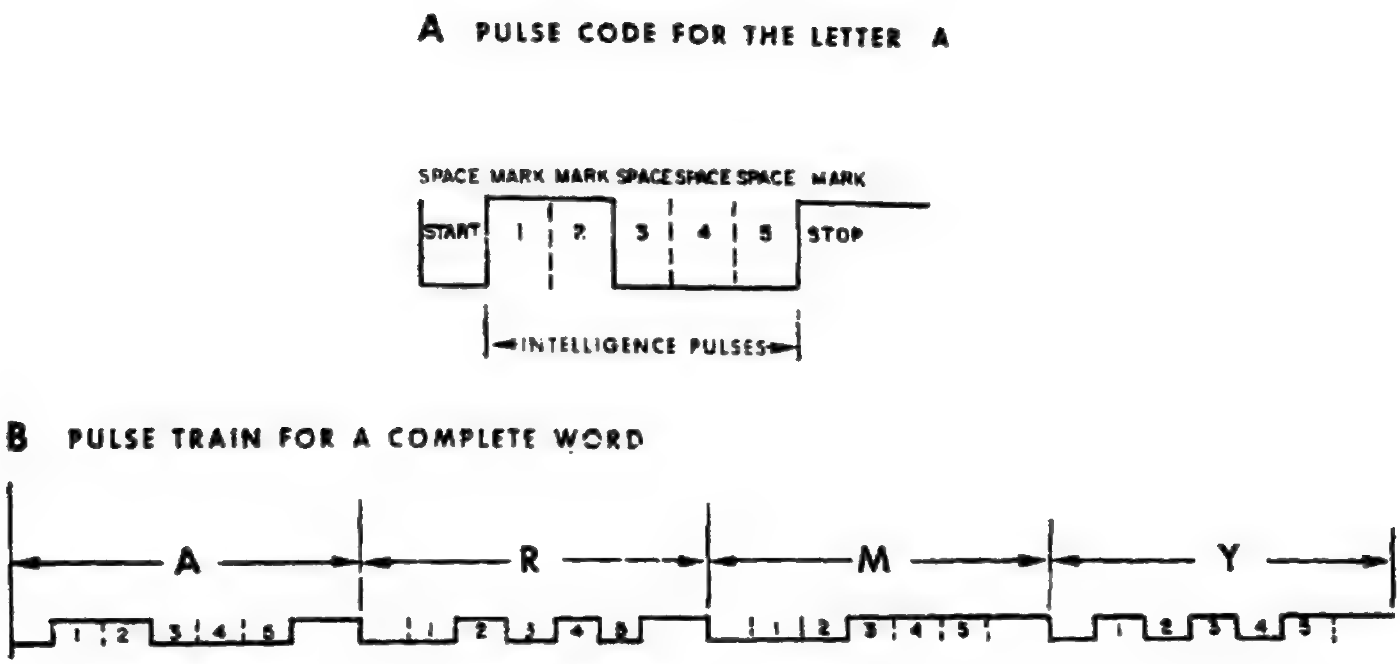

FIGURE 77. Using the Baudot Code.

milliseconds for the stop pulse. Thus it takes 6 x 22 plus 31 or 163 milliseconds to transmit one letter or one figure. An average word is 5 characters (letters), with a space after each word, making a total of 6 characters or 6 operations. Therefore, it takes 6 x 163 or 978 milliseconds (.978 second) to transmit an average word. The rate of transmission is 60 seconds divided by .978 second per word which equals 61.3 WPM. This rate is generally rounded off and referred to as 60 WPM.

b. Baud. Instead of using the term words per minute to express the rate of a teletypewriter system, a different term, the baud, is used internationally.

(1) The term baud expresses the rate of sending the shortest pulse in a character. One baud is a speed on 1 pulse per second. Twenty baud is a speed of 20 pulses per second.

(2) To determine the baud number, divide 1 second by the time duration of one intelligence pulse. For example, 60 WPM equipment transmits at a rate of 1 second divided by 0.022 second of 45.5 baud.

(3) Standard teletypewriter equipment that operates at 45.5 baud (60 WPM) can be modified to operate at either 61.0 baud (75 WPM) or 74.2 baud (100 WPM). To do this, certain gears within the teletypewriter must be changed. As a result, the pulse length or duration is shortened and the baud number is increased.

c. Bits per second. The term bits per second is sometimes used to describe the rate. A bit is equivalent to a pulse. If all pulses including the start and stop pulses last for the same length of time, the bit rate is exactly the same as the baud number. The term bit is used in data communication.

d. Operations per minute. Operations per minute (which is the same as the number of characters per minute) is another term used to designate the rate of teletypewriter equipment. 61.3 WPM is equivalent to 61.3 WPM x 6 characters per word or 368 operations per minute.

e. Dot frequency. There's still another term that's used--the dot frequency. A dot cycle is defined as the time duration of a mark plus a space. Since a mark and a space take 44 milliseconds (22 x 2), the dot frequency is 1 second divided by 0.044 second or 22.75 Hz. Note that the dot frequency is one half the baud number (b above).

80. Other Teletypewriter Terms.

a. Working with teletypewriter equipment, you'll often hear the terms, "running closed" and "running open."

(1) "Running closed" means that the machine is receiving a steady mark signal. When it is running closed, the teletypewriter does not perform any mechanical operations.

(2) "Running open" means that the machine is receiving a steady space signal. You can see the teletypewriter performing mechanical operations, but it does not print out any messages.

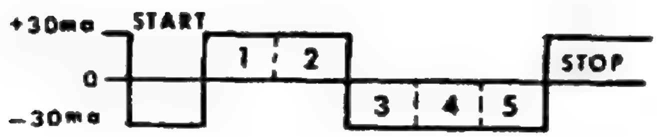

FIGURE 78. Polar signals for the Letter A.

b. A term less frequently used is "lock up condition." It means you are receiving a steady mark when you know you should be receiving an input signal. For example, you have a lock up condition when the teletypewriter starts typing a message from a distant terminal and then it suddenly stops typing before the message is completed. This is usually caused by a defect of other equipment in the circuit.

CHAPTER 10

TELETYPEWRITER CIRCUITS

81. Kinds of Pulses in DC Teletypewriter Circuits.

Either neutral or polar pulses may be used to represent the Baudot code in dc teletypewriter circuits.

a. Neutral pulses are characterized by current flow for a mark, and no current flow for a space, as shown in figure 77.

b. Polar signals are characterized by current flow in one direction for a mark, and current flow in the opposite direction for a space. Pulses for the letter A would look like those of figure 78. In this figure, the direction of the current is represented by positive and negative pulses. In polar transmission there's always current in the circuit; it flows either in one direction or the other.

c. Although circuits for polar transmission are more expensive and difficult to install and maintain than those for neutral transmission, polar transmission is superior when only wire facilities are used. You can transmit over a greater distance with polar pulses because polar transmission is not readily affected by the distributed capacitance and inductance in the line connecting the transmitting and receiving stations. Also, since current values are lower in polar transmission, the power losses on the line are less.

82. Introduction to DC Teletypewriter Circuits.

Direct current (dc) teletypewriter circuits get their name from the fact that direct current flows in the wires or cables that connect the sending and receiving stations. You can use dc teletypewriter circuits for communication over distances up to several miles.

83. The Principal Parts of a Teletypewriter.

The teletypewriter we will use in this text to describe dc teletypewriter circuit consists of four principal parts (fig. 79), as follows.

a. Voltage source. In teletypewriter schematic diagrams, the voltage source is usually shown as a battery. In practice, rectifiers are normally used. Moreover, it is common to speak of the rectifier output voltage as the battery voltage.

b. Transmit mechanism. This is also called a keyboard transmitter. Its purpose is to change the letters and figures you type on the keyboard into the marks and spaces of the Baudot code. We'll represent the transmit mechanism by the transmitting contacts schematic symbol. In this switch symbol, the left arrowhead represents the closed circuit contact for marks and the right arrowhead represents the open circuit contact for spaces.

c. Receive mechanism. This is also called a page printing mechanism. Its purpose is to change the marks and spaces into letters and figures which are printed on paper. We'll represent the receive mechanism by the selector magnet schematic symbol. A selector magnet is an electromagnet. Its armature operates in one direction for marks and in the other direction for spaces.

d. Current adjust potentiometer. You use this potentiometer and a milliammeter (not shown) to adjust the current by changing the resistance in the teletypewriter circuit.

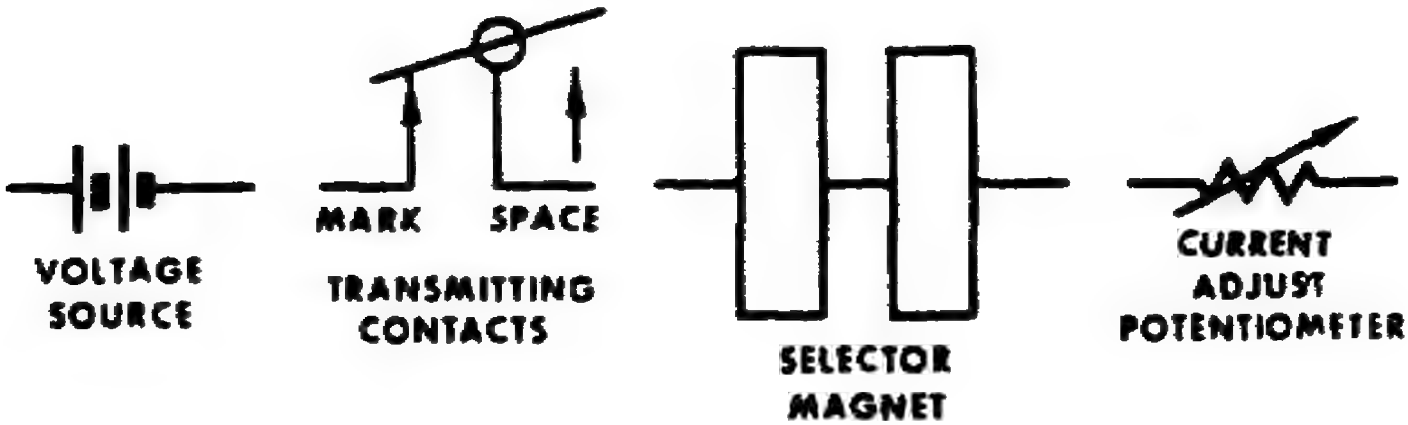

FIGURE 79. Principal Parts of a Teletypewriter.

84. The One-Way-Only Teletypewriter Circuit.

a. The simplest of teletypewriter circuits is used to transmit messages in one direction only. Hence, it is called a one-way-only circuit (fig. 80). In this circuit the receiving teletypewriter is simply a monitor. A common application is the ticker-tape machine in the office of a stock broker.

b. The four principal parts of a teletypewriter are connected in series in the sending teletypewriter. In the receiving teletypewriter there is no keyboard and transmitting contacts are unnecessary. The sending and receiving teletypewriters are connected by a wire or cable known as the line.

c. In a ground-return circuit such as that shown in figure 80, each teletypewriter is grounded by means of a grounding rod. The earth thus provides a return path for current flow. Most of the circuits in this text are shown with a ground-return path to make the circuit drawings easy to understand. In practice, however, full-metallic circuits are usually used. For a full-metallic circuit, all the ground points at the sending station are connected to all the ground points at the receiving station by an additional line wire or cable. Full-metallic circuits offer less resistance to current flow. Also, a full-metallic circuit must be used for classified message traffic. It makes it more difficult for the enemy to intercept the messages.

d. Trace the path of current flow in the one-way-only circuit in figure 80. Start at the negative side of the voltage source. Go, in sequence, through the transmitting contacts of the sending teletypewriter, selector magnet, current adjust potentiometer, the line, and current adjust potentiometer of the receiving teletypewriter selector magnet, to ground, up from ground at the sending teletypewriter, and return to voltage source.

e. When the operator sends a message, his teletypewriter prints what is known as <u>home</u> or <u>local</u> <u>copy</u>. Simultaneously, the receiving teletypewriter automatically prints <u>receive</u> <u>copy</u>.

f. Neutral signals are transmitted over the line in the circuit of figure 80. The mark current is usually adjusted for 60 milliamperes (ma), although in some equipment other predetermined current values such as 20 ma are used.

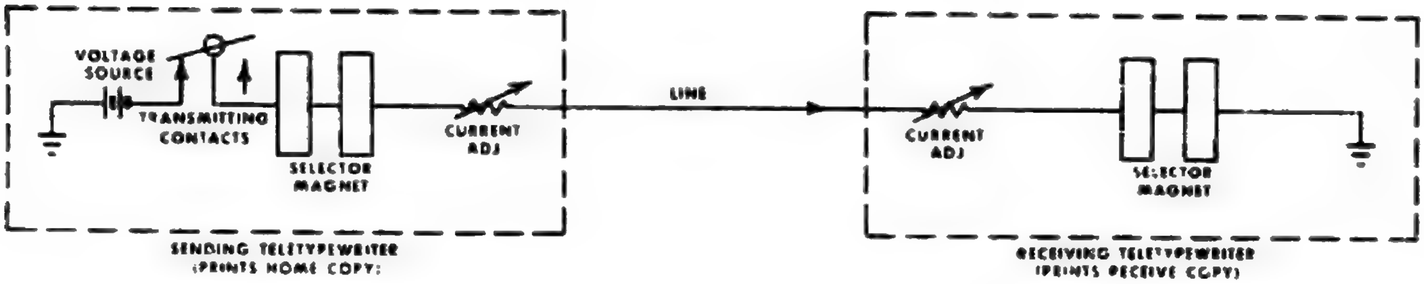

FIGURE 80. One-Way Only Teletypewriter Circuit for Neutral Signals.

85. <u>The Half-Duplex Teletypewriter Circuit</u>.

a. Figure 81 shows a half-duplex teletypewriter circuit. You can use this circuit to send messages either from west to east, or from east to west, but not in both directions at the same time. It is a one-way reversible circuit. This circuit may be used when the volume of message traffic is low.

b. The half-duplex circuit consists of two teletypewriters and the line as in the one-way-only circuit. When you are sending a message from the west teletypewriter, the transmitting contacts at the east teletypewriter <u>must</u> remain closed so that you'll have a closed circuit for mark current. At this time, your teletypewriter will print home copy and the east teletypewriter will print receive copy. When the operator at the east teletypewriter is sending a message to you, your transmitting contacts must remain closed. At this time, of course, your teletypewriter will print receive copy and the east teletypewriter will print home copy.

c. Whether you are sending or receiving at the west teletypewriter, current flow is from the battery through your transmitting contacts, selector magnet, current adjust potentiometer and through the line. It then flows through the corresponding parts in the east teletypewriter, to ground, to ground at the west teletypewriter, and back to the battery.

d. When you are receiving a message at the west teletypewriter, you can interrupt the operator at the east teletypewriter to ask him a question by pressing the BREAK key. This operation automatically opens the circuit and nothing is printed at either station. The east teletypewriter operator knows this is a signal for him to stop sending and wait for your message.

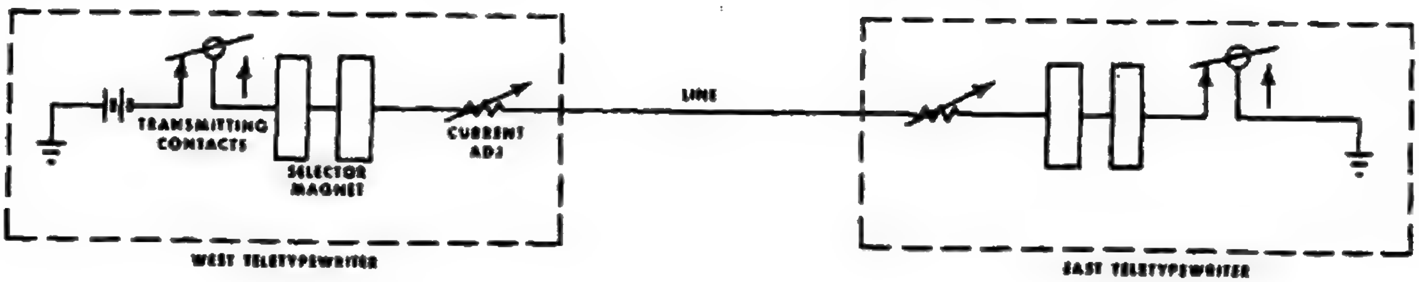

FIGURE 81. Half-Duplex Teletypewriter Circuit (One Way Reversible) for Neutral Signals.

86. The Full-Duplex Teletypewriter Circuit.

a. Using a full-duplex teletypewriter circuit like the one shown in figure 82, you can transmit and receive messages at the same time. Thus, this circuit can handle twice the traffic of a half-duplex circuit.

b. A full-duplex circuit consists of two separate series circuits, each of which has a voltage source, transmitting contacts, current adjust potentiometer, a line wire or cable, and a selector magnet. Because the transmitting contacts of one teletypewriter are not in a series with the selector magnet of that teletypewriter, neither teletypewriter will print home copy. However, each teletypewriter prints receive copy.

c. The current path for transmission from west to east is from the negative side of the battery at the west teletypewriter in sequence through:

(1) The transmitting contacts.

(2) The current adjust potentiometer.

(3) The line.

(4) The selector magnet at east.

(5) Ground at east.

(6) Ground near the battery at west.

(7) The positive side of the battery.

d. The operator of the station to whom you are sending cannot break into your transmission as he can in a half-duplex circuit. He'll have to send a message to you on the second series circuit.

e. A disadvantage of the two-telephone full-duplex circuit is that neither station prints home copy. To overcome this disadvantage, two teletype-writers can be used at each station as shown in figure 83. Here, home and receive copy are printed at each station.

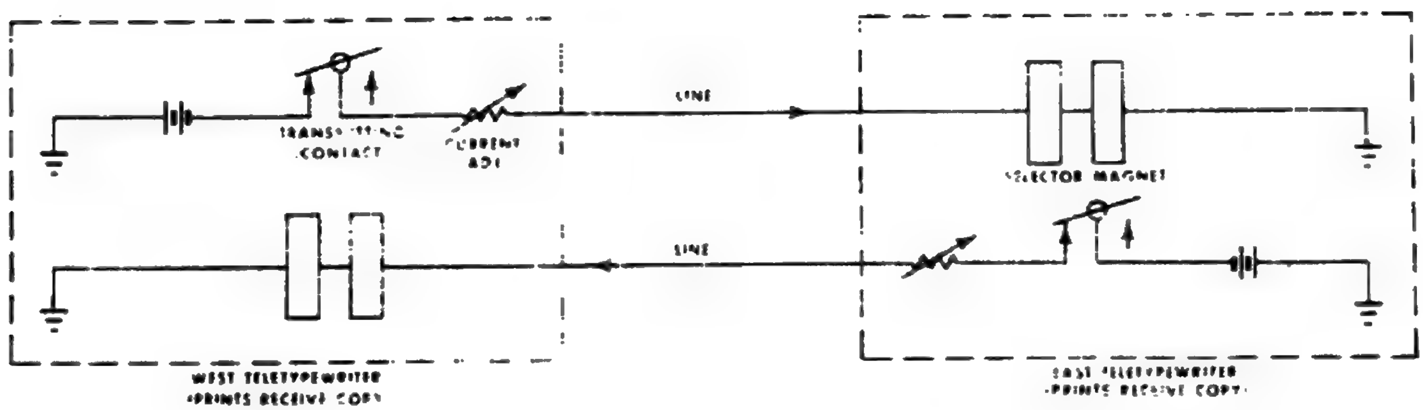

FIGURE 82. Full-Duplex Teletypewriter Circuit (Two Way) for Neutral Signals.

87. Using Polar Line Signals.

a. There is less distortion and smaller line loss when polar signals are sent out over the line instead of neutral signals. To convert from neutral to polar operation requires more equipment, but the advantages are a longer range of transmission and greater error-free traffic.

b. To change neutral to polar signals, you need a dc repeater at both the sending and receiving stations. A dc repeater includes a send relay, a receive relay, and associated supply to voltages. The send (neutral-to-polar) relay changes the neutral signals to polar signals. The receive (polar-to-neutral) relay does the opposite--it changes polar signals from the line back to neutral signals to operate the receive teletypewriter. The polar signals are usually 30 ma current signals in either direction. However, different current values, such as 20 ma can be used, depending on system design, so long as the current in each direction is the same.

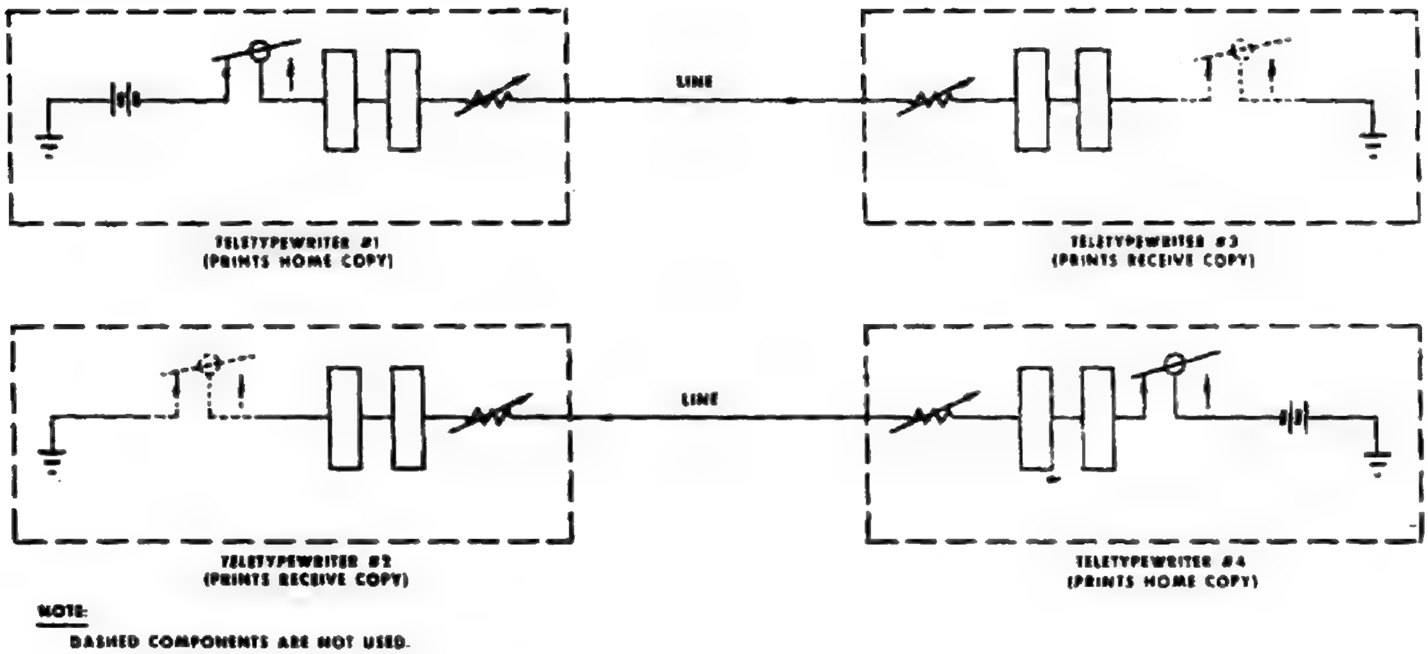

FIGURE 83. Full-Duplex Circuit -- Home and Receive Copy Printed at Each Station.

88. How the Polar Send Relay Works.

a. A polar relay (fig. 84) consists of a flexible armature with one end anchored in a permanent magnet. It has pole pieces for sensitivity adjustment, and two windings around the armature--a bias winding and a line winding.

b. The bias winding has a fixed value of 30 ma flowing through it when the line winding is connected to a neutral-polar switch. When the line winding receives neutral signals, the switch is closed. (When this type of relay has polar signals applied to the line windings as in the receive relay, the neutral-polar switch is opened.)

c. A polar relay operates on the principle of balanced magnetic fields. Assume for the moment that the armature sits precisely half-way between the pole pieces and that neither winding is connected for current flow. The shunt path, consisting of the permanent magnet and the soft-iron armature, balances the lines of force between the armature and pole pieces. If the armature is forcefully moved toward one pole piece or the other, the armature will snap over that way and will stay there because the magnetic field is now unbalanced in that direction. Moreover, the armature will remain there unless forcefully moved past midpoint toward the other pole piece, at which time it will remain on the other contact until moved.

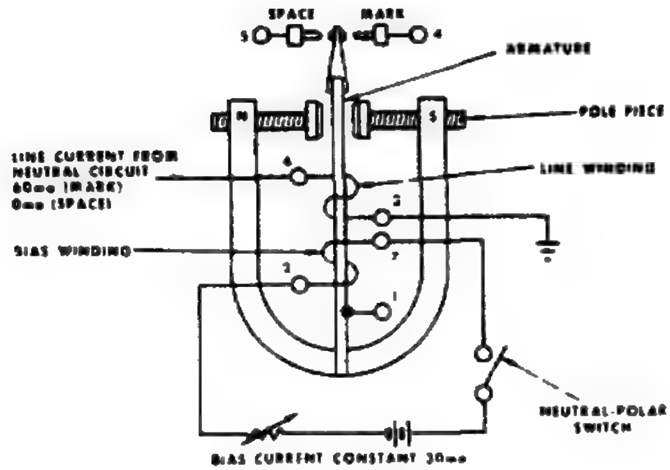

FIGURE 84. The Send (Polar) Relay Wired for Neutral-to-Polar Operation

d. The direction of bias current is important. It <u>must</u> flow through the bias winding to cause the armature to move to the SPACE contact. When this condition exists, the relay is said to be <u>poled</u> <u>spacing</u>. (If bias current flows in the opposite direction, the relay is said to be <u>poled</u> <u>marking</u>.)

e. The input to the line winding of a send relay is the neutral signal from a teletypewriter. The magnetic force set up by the line winding mark current completely overcomes the force set up by the bias winding and the armature swings over to the MARK contact. When current ceases (space), the magnetic force set up by the bias winding swings the armature back to the SPACE contact. Each mark pulse causes the armature contact to touch the MARK

contact. The bias winding causes the armature to swing to the SPACE contact during each space (no current). The bias winding and its current, therefore, act as an electrical spring that returns the armature to the SPACE contact. The distance between the MARK and SPACE contacts and the armature is very small, so the transit time between repeated pulses is very short.

f. The direction of current flow in the line winding is important. If the current is turned over--that is, if it flows in a direction to aid the bias winding instead of opposing its effect. The result is that the armature will remain on the SPACE contact constantly and the receiving teletypewriter will run open.

89. The Polar Half-Duplex Teletypewriter Circuit.

a. The polar half-duplex circuit uses a teletypewriter and a dc repeater at each end of the line as shown in figure 85. The wire connecting the teletypewriter to the dc repeater is known as loop. The west send relay converts neutral signals from the west teletypewriter into polar signals which are sent over the line. The east receive relay converts received polar signals into neutral signals so that receive copy can be printed on the east teletypewriter.

b. When you are transmitting from west to east, signal flow is from the west transmitting contacts in sequence through the following:

(1) The west selector magnet (which produces home copy).

(2) The current adjust potentiometer.

(3) The line winding and mark (M) or space (S) contact of the send relay.

(4) The current adjust potentiometer at the west repeater.

(5) The line.

(6) The winding and mark (M) or space (S) contact of the east receive relay.

(7) The line winding of the east send relay.

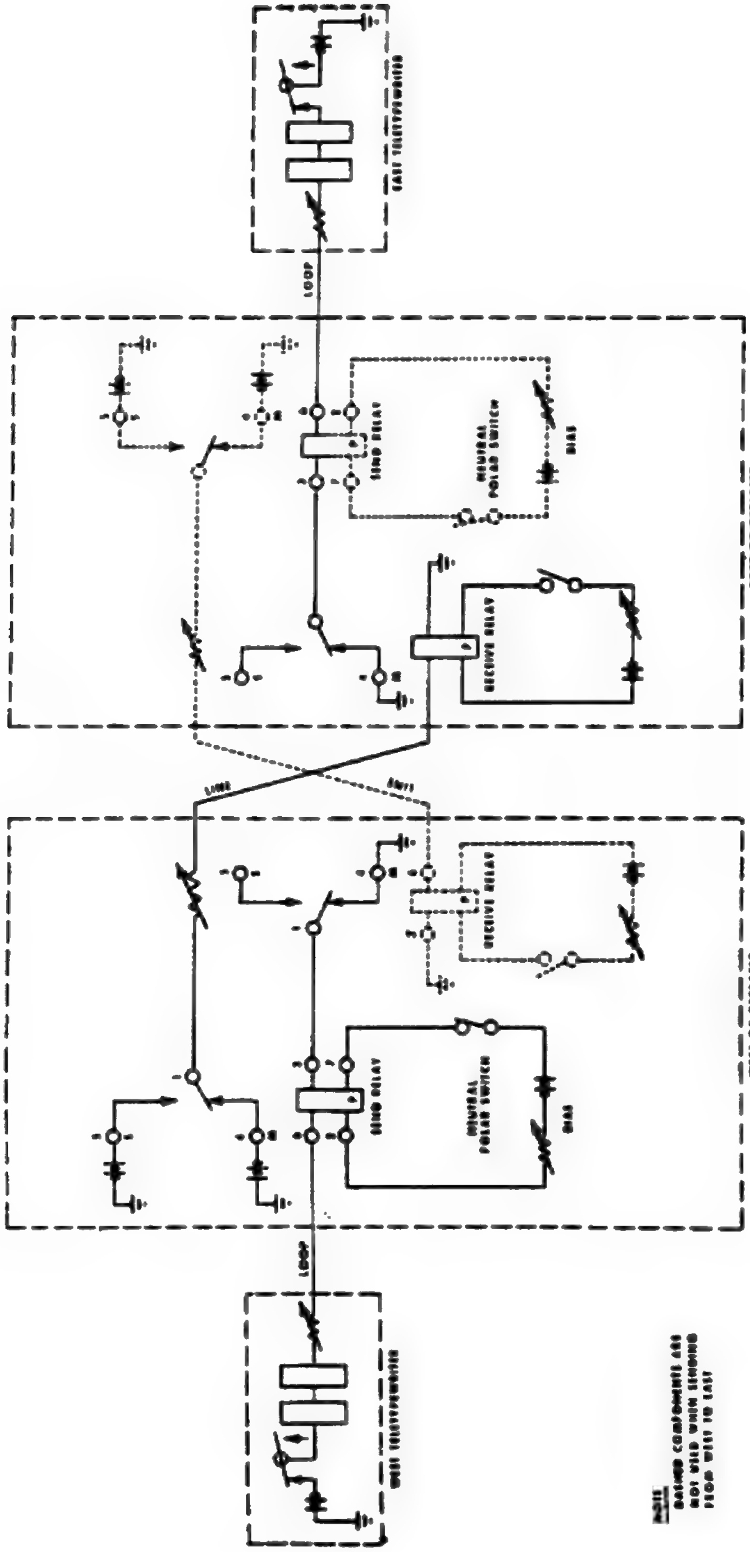

FIGURE 85. Half-Duplex Teletypewriter Circuit -- Polar Line Signals, One Way Reversible Transmission.

(8) The current adjust potentiometer.

(9) The east selector magnet (which produces receive copy).

c. The lighter area in figure 85 is not a part of the signal path when you are sending from west to east. However, the parts in this lighter area do have current flowing in them. For example, the line winding of the relay at the west dc repeater has current flowing through it continuously to hold its armature at the mark (M) contact.

d. When you are transmitting a mark from west to east, three circuits work in conjunction with one another. The circuits are as follows:

(1) The west loop circuit. In this circuit current flows from the negative side of the battery near the transmitting contacts, through the transmitting contacts, the selector magnet, the current adjust potentiometer, the line winding of the send relay, the mark contact of the receive relay, to ground at the receive relay, and up from ground to the battery.

(2) The line circuit. In this circuit current flows from the negative side of the battery near the mark contact, of the west send relay, through the mark contact, the current adjust potentiometer, the line, the winding of the east receive relay, to ground, and up from ground to the battery near the mark contact of the west send relay. The current in this circuit is normally adjusted to 30 ma, although in some equipment, it may be 20 ma.

(3) The east loop circuit. In this circuit the current flow path is the same as that in the west loop circuit.

e. The bias circuit for each send relay has current flowing in it at all times. Current flows from the negative side of the battery through the bias current adjust potentiometer to the bias winding (contacts 2 and 7), and returns to the positive side of the battery. Using a milliammeter (not shown), you adjust the current so that it is one-half of the line winding current when a mark is being transmitted.

f. When you are sending a space at the west station, there is no current in the west loop circuit. The bias winding of the send relay causes the armature to snap back, breaking the mark (M) circuit and making contact with the space (S) circuit. Current then flows in the line circuit in the

opposite direction. This, in turn, causes the east receive relay to be magnetized in the opposite direction, which causes the mark (M) contact to open. Thus, the east loop circuit will have no current.

g. In a polar half-duplex circuit when the west teletypewriter is sending, it prints home copy and, at the same time, the east teletypewriter prints receive copy.

90. The Polar Full-Duplex Teletypewriter Circuit.

a. In a polar full-duplex teletypewriter circuit (fig. 86), messages can be transmitted in both directions at the same time. Hence, the volume of traffic that can be handled is twice that of a half-duplex circuit. When a third wire or cable is added for the return path of current flow (full-metallic), the stations can be up to 20 miles apart.

b. The signal and circuit paths are similar to those of the polar half-duplex circuit except that the transmitting contacts and selector magnet of each teletypewriter are not in series. The signal from the sending teletypewriter goes directly to the line windings of its associated send relay; therefore, no home copy is printed.

c. The disadvantage of this circuit is that home copy cannot be printed. However, you can overcome this disadvantage by using four teletypewriters as we have already shown in the neutral full-duplex circuit (fig. 83).

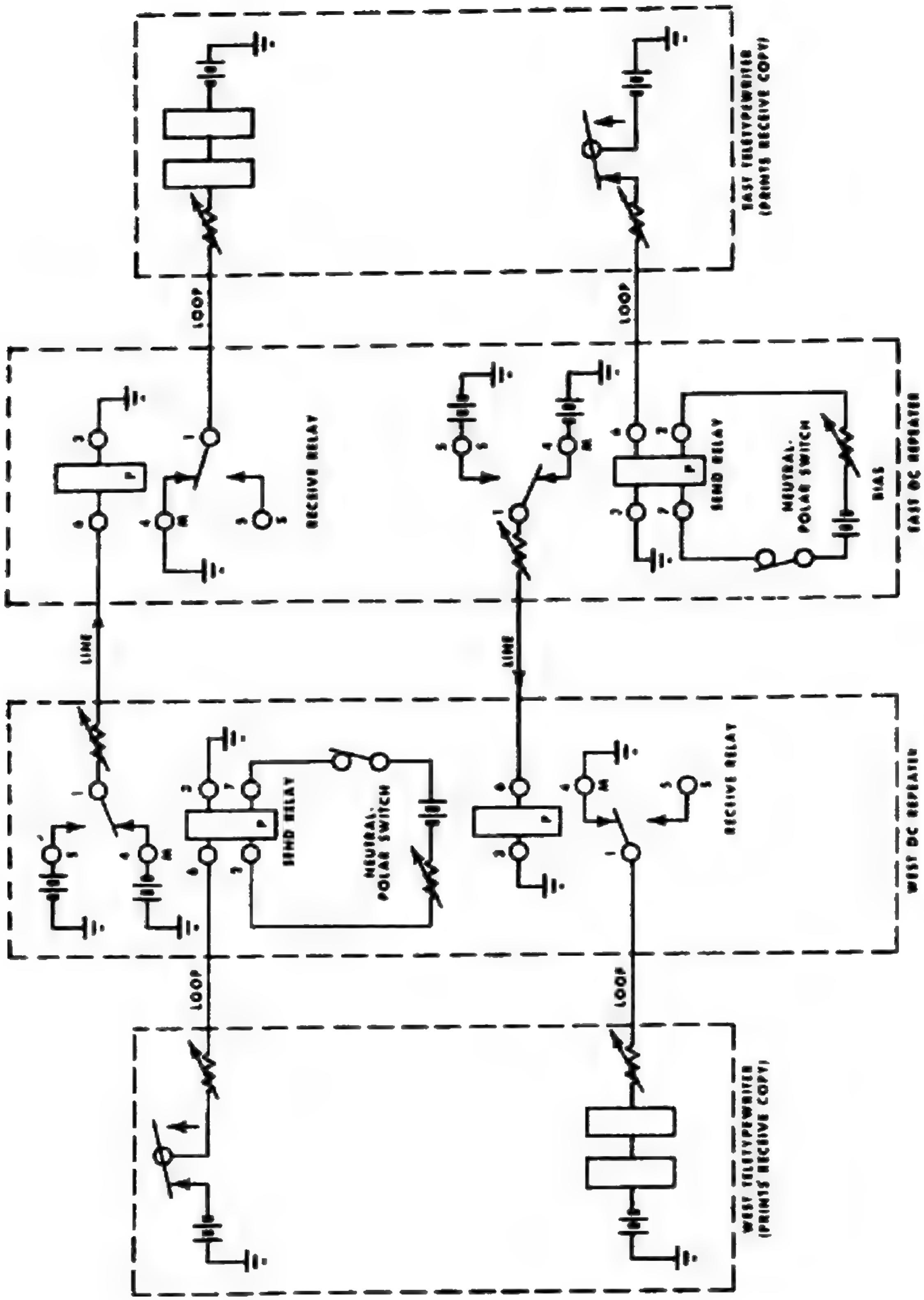

FIGURE 86. Full-Duplex Teletypewriter Circuit -- Polar Line Signals, Two-Way Transmission.

91. The Simplexed Teletypewriter Circuit.

a. Superimposing a teletypewriter circuit on an existing telephone circuit saves wire. The circuit that results is called a simplexed teletypewriter circuit.

b. A simplexed teletypewriter circuit is derived from a telephone circuit by using the pair of parallel wires of the telephone set as one conductor of the teletypewriter circuit and providing a ground return for the second conductor (fig. 87). A repeating coil is installed at each end of the telephone circuit and the teletypewriters are connected between the midpoint of the line winding of each repeating coil and ground. Direct current from the teletypewriter at the west station divides and flows in opposite directions through the line winding of the west repeating coil, over both lines in parallel, through the line winding of the east repeating coil, and through the east teletypewriter to ground.

c. If the resistance of each wire in a pair is identical--that is, the lines are balanced--the operation of the telephone and the telegraph will not interfere with each other. This is because the teletypewriter currents in the line windings of each repeating coil are opposing. They will induce no net voltage in the primary windings of the repeating coils. Also, the center taps of the line windings of the repeater coils are used to ac current from telephone operation will not affect teletypewriter operation.

92. The Phantom Teletypewriter Circuit.

a. You can have two telephone circuits and a full-metallic teletypewriter circuit operating at the same time (figure 88). This is called a phantom teletypewriter circuit. The pair of wires of line side circuit #1 is one conductor for the teletypewriter circuit and the pair of wires of line side circuit #2 is the other conductor.

b. The operation of the circuits will not interfere with each other as long as the lines are balanced.

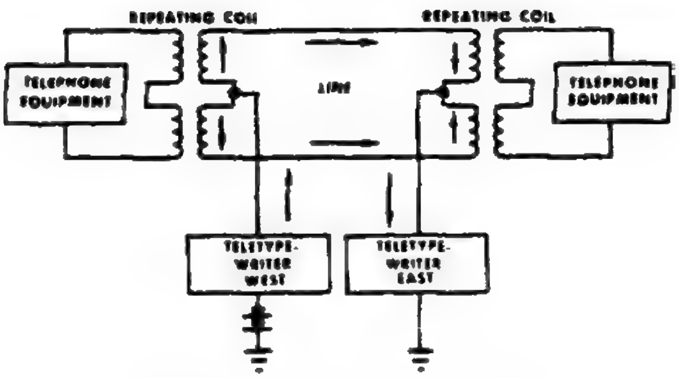

FIGURE 87. Simplexed Teletypewriter Circuit (Ground Return)

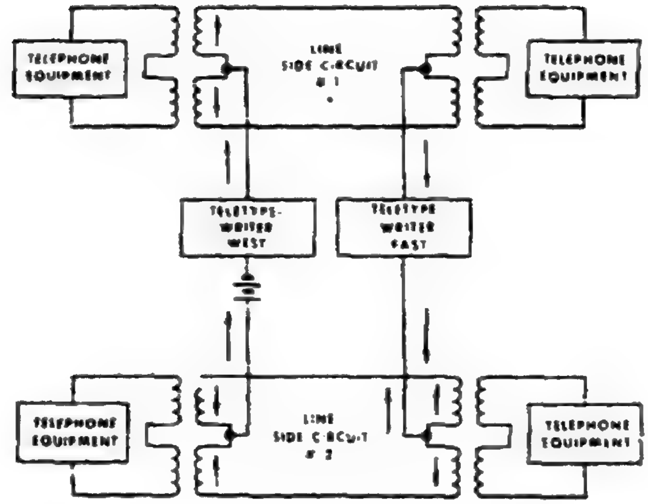

FIGURE 88. Phantom Teletypewriter Circuit (Full-metallic).

93. The Simplexed Teletypewriter Phantom Telephone Circuit.

You can have three telephone circuits and one teletypewriter circuit in operation at the same time using only two pairs of line wires and a ground return for the teletypewriter circuit (fig. 89). This is done by adding a simplexed teletypewriter circuit to a phantom telephone circuit. In this case the third telephone circuit between the line side circuits in the phantom circuit.

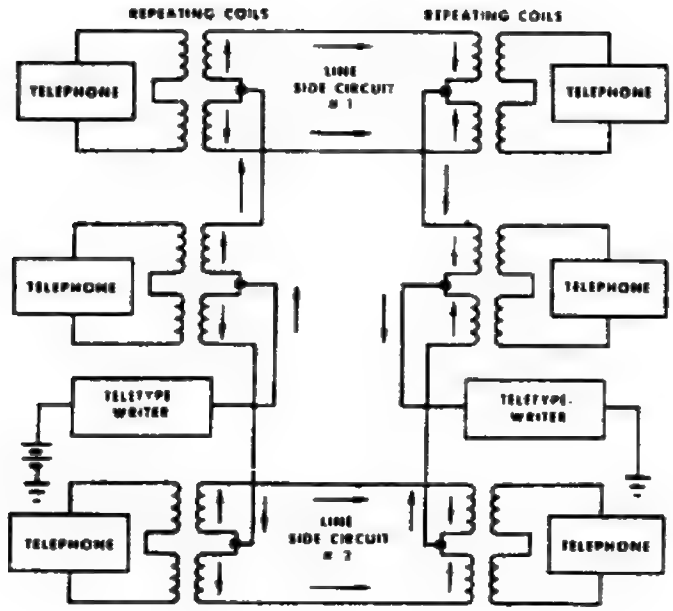

FIGURE 89. Simplexed Teletypewriter Circuit, Phantom Telephone Circuit.

94. Important Points to Remember.

a. In a half-duplex circuit, if both stations are transmitting at the same time, the printed copy would be garbled because each teletypewriter would try to print both home copy and receive copy at the same time.

b. Current adjust potentiometers allow the current to be adjusted to a predetermined value.

c. Full-metallic circuits are always used for classified messages.

d. You need twice as many line wires or cables in a full-duplex circuit.

e. The two windings on a polar relay are called the line winding and the bias winding.

f. DC teletypewriter circuits can use existing telephone circuits to interconnect the transmitting and receiving stations; thus, the installation of line wires or cables is unnecessary.

LESSON 4 EXERCISES

In each of the following exercise, select the ONE answer that BEST completes the statement or answers the question. Indicate your solution by circling the letter opposite the correct answer in the subcourse booklet.

1. A communication system consisting of teletypewriters connected by a dc signal line is essentially a telegraph system in which the:

   a. stop pulse need never be transmitted.

   b. first impulse of a code character is always a mark.

   c. line carries no current until the operator starts sending.

   d. receiving teletypewriter automatically translates the coded pulses into words.

2. A voice-frequency (vf) telegraph terminal operates on the principle that marks and spaces in a teletypewriter output signal cause:

   a. an oscillator to shift from one frequency to another.

   b. the amplitude to change in a constant-frequency signal.

   c. a tone to pass during the marking interval and disappear during the spacing interval.

   d. the tone to pass during the spacing interval and disappear during the marking interval.

3. The function of the stop pulse in a character of the Baudot teletypewriter code is to:

   a. signal the end of transmission.

   b. stop the motor when the message is finished.

   c. indicate a momentary pause in the transmission of a message.

   d. synchronize the receiving teletypewriter with the sending teletypewriter.

4. What letter of the Baudot teletypewriter code will be printed by a teletype-writer which receives the waveform shown in figure 90?

a. Q
b. J
c. W
d. X

FIGURE 90. Teletypewriter Signal Wave Form.

SITUATION

Information regarding the Baudot teletypewriter code is given in Table 3-1. Using the formulas below the table, determine the approximate missing values and enter them in the proper columns.

TABLE 3-1

TELETYPEWRITER CODE CHARACTERISTICS

Speed WPM	Unit Pulse Length (ms)	Baud	Dot Frequency	Bits Per Second	Length of Stop Pulse(ms)	Total Char Length(ms)
60	22	45.5	23 Hz	45.5	31	163
75		61.0	30.5 Hz	61.0	25	133
100	13.5			74.2		100

Formulas:

1. To find Baud: B = 1 sec/P, where P is length (in seconds) of one unit pulse.

2. To find pulse length: P = 1 sec/B.

3. To find dot frequency: F_d = 1 sec/2P.

Exercises 5 thru 8 are based on the above situation.

5. The term baud has been internationally adopted to express the rate of teletypewriter transmission. A 100-per-minute teletypewriter transmits at the rate of:

a. 20.0 baud.

b. 45.5 baud.

c. 61.0 baud.

d. 74.2 baud.

6. The unit pulse length for 75 WPM transmission speed is approximately:

a. 13 ms.

b. 18 ms.

c. 22 ms.

d. 30 ms.

7. The dot frequency of the teletypewriter signals at 100 WPM transmission speed is approximately:

a. 22 Hz.

b. 30 Hz.

c. 37 Hz.

d. 45 Hz.

8. The length of the stop pulse at 100-WPM transmission speed is approximately:

a. 19 ms.

b. 22 ms.

c. 25 ms.

d. 31 ms.

9. Assume that one of the operators in your station reports that a teletypewriter is "running open." This means that the teletypewriter is receiving a steady:

a. mark signal--it does not perform any operations.

b. mark signal--it suddenly stops in the middle of a message.

c. space signal--it performs mechanical operations but does not print.

d. mark and space signal in alternation--it prints a garbled message.

10. The advantages gained by using neutral signals instead of polar signals in dc teletypewriter circuits are:

a. circuits are less expensive and they are easier to install.

b. circuits are easier to install and the signals can be transmitted over greater distances.

c. Signals can be transmitted over greater distances and they are not readily affected by inductance and capacitance in circuits.

d. signals are not readily affected by inductance and capacitance in circuits, and the line power loss is less.

11. Assume that you are tracing the current path on the schematic diagram of a dull-duplex teletypewriter circuit. What symbol would you look for to locate the voltage source?

a. Relay.

b. Battery.

c. Potentiometer.

d. Selector magnet.

12. In a neutral half-duplex teletypewriter circuit, if you are receiving a message and you want to signal the distant end to stop sending, you must:

a. press the BREAK key.

b. turn your teletypewriter machine off.

c. type on your machine and tell him to stop sending.

d. wait until he stops sending, as there is no way to signal him.

13. A teletypewriter circuit that you can use to send messages whether from west to east or from east to west, but not in both directions at the same time, is a:

a. simplex circuit.

b. half-duplex circuit.

c. full-duplex circuit.

d. one-way-only circuit.

14. Assume that you are using a teletypewriter order wire, and you are able to transmit and receive at the same time but do not get a home copy of your transmission. What type of teletypewriter circuit is used for your order wire?

a. Simplex.

b. Half-duplex.

c. Full-duplex.

d. One-way-only.

SITUATION

The current path for transmission from west to east on a full-duplex teletypewriter circuit is shown in figure 86. Each circuit component is given an identifying number in this situation. Trace the current path through the circuit, using the list of numbers below.

1. The line.

2. Ground at east.

3. The transmitting contacts.

4. The selector magnet at east.

5. Ground near the battery at west.

6. The positive side of the battery.

7. The current adjust potentiometer.

Exercise 15 is based on this situation.

15. The current flows through the circuit in sequence through:

a. 1, 4, 6, 3, 2, 5, 7.

b. 4, 5, 1, 3, 2, 7, 6.

c. 7, 6, 2, 4, 5, 1, 3.

d. 3, 7, 1, 4, 2, 5, 6.

16. The two windings around the armature of a polar relay are called the:

a. bias winding and the line winding.

b. send winding and the receive winding.

c. polar winding and the neutral winding.

d. current adjust winding and the voltage adjust winding.

17. Analysis of figure 84 shows that the input circuit to the send polar relay is connected to terminals:

a. 5 and 4.

b. 2 and 7.

c. 6 and 3.

d. 1 and 4.

18. The schematic diagrams in figures 85 and 86 have many similarities. However, one difference between them is that in figure 86:

a. the send loop is entirely independent of ground.

b. battery does appear on the space contacts of the receive relays.

c. there is no series connection between selector magnets and keyboard contacts.

d. the direction of current flow is reversed in the send relay windings.

19. A teletypewriter circuit derived from using a telephone circuit and ground return is called a:

a. polar phantom teletypewriter circuit.

b. full-duplex teletypewriter circuit.

c. half-duplex teletypewriter circuit.

d. simplexed teletypewriter circuit.

20. In the circuit shown in figure 88, the teletypewriters will not interfere with telephones as long as the:

a. lines are balanced.

b. line windings are not center-tapped.

c. battery is removed from the teletypewriters.

d. teletypewriters use a full-metallic return circuit.

CHECK YOUR ANSWERS AGAINST LESSON 4 SOLUTION SHEET (PAGE 193) AND MAKE NECESSARY CORRECTIONS.

HOLD ALL TEXTS AND MATERIALS FOR USE WITH EXAMINATION.

LESSON SOLUTIONS

SIGNAL SUBCOURSE SSO 330 .... Introduction to Telephone and Telegraph Transmission

LESSON 1 .... Sound and Telephony

1.	c	11.	a
2.	b	12.	b
3.	c	13.	c
4.	a	14.	b
5.	d	15.	d
6.	b	16.	b
7.	b	17.	b
8.	c	18.	b
9.	b	19.	a
10.	c	20.	a

LESSON 2 .... Telephone Systems

1.	c	11.	d
2.	a	12.	b
3	b	13.	d
4.	c	14.	c
5.	d	15.	a
6.	b	16.	a
7.	d	17.	d
8.	d	18.	b
9.	b	19.	b
10.	c para 43b	20.	a

LESSON 3 .... Transmission Lines

1.	c para 63	11.	b
2.	d para 63 a	12.	a
3.	a para 62c	13.	d
4.	a	14.	d
5.	d	15.	a
6.	d	16.	d
7.	b	17.	c
8.	d	18.	d
9.	d	19.	b
10.	b		

LESSON 4 . ... Fundamentals of Teletypewriter

1.	d	11.	b
2.	a	12.	a
3.	d	13.	b
4.	b	14.	c
5.	d	15.	d
6.	b	16.	a
7.	c	17.	c
8.	a	18.	c
9.	c	19.	d
10.	a	20.	a